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SCIENTIFIC AMERICAN MONTHLY

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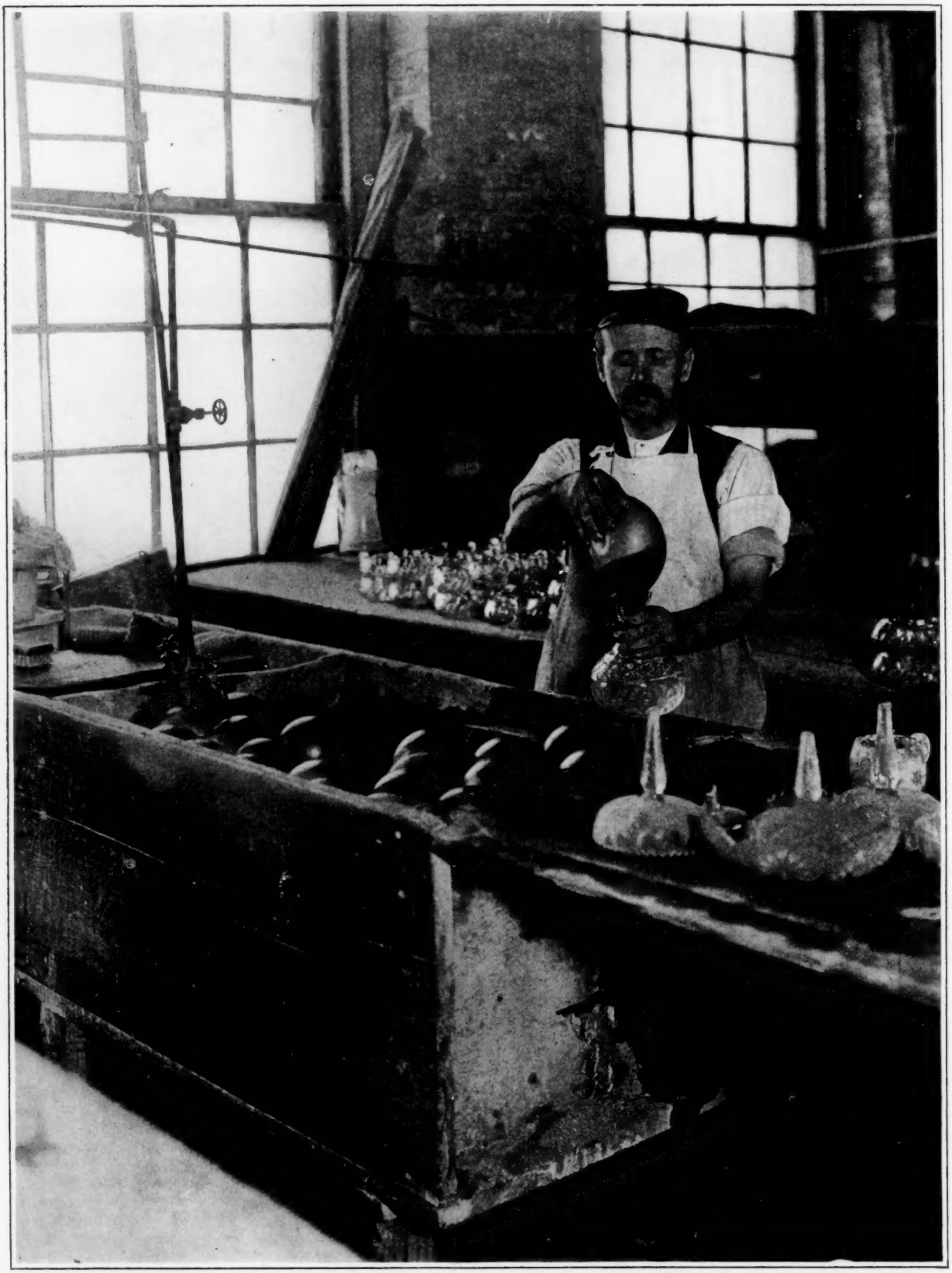

USING A RUBBER BOTTLE TO FORCE WATER AND ACID INTO A CARAFE SO AS TO CLEAN OUT ANY SEDIMENT IT MIGHT CONTAIN. (SEE PAGE 30.)

SCIENTIFIC AMERICAN MONTHLY

VOLUME I
NUMBER 1

NEW YORK, JANUARY, 1920

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SUCCESSOR TO THE SCIENTIFIC AMERICAN SUPPLEMENT.

IN the SCIENTIFIC AMERICAN of December 4, 1875, a new journal was announced to be known as the SCIENTIFIC AMERICAN SUPPLEMENT. It was a momentous period in our national history. Our industries had fully recovered from the ravages of the Civil War, and at this the one hundredth anniversary of the founding of our Republic, we were going to demonstrate to the world by a great International Exposition the progress we had made in the arts and sciences. There was a wide-spread interest in technology and it was felt by the publishers of the SCIENTIFIC AMERICAN that there was a need for a journal which would meet the desire for information of a more technical character than could properly be published in the SCIENTIFIC AMERICAN. The wisdom of publishing the SUPPLEMENT was demonstrated when the first issue bearing date of January 1, 1876, was placed on sale a week in advance of that date and all copies were exhausted before the first of the year, making it necessary to publish a second edition.

We have come to another such momentous period in our history. Again we feel that a special journal is demanded to meet the requirements of the time. The great war has awakened in the American public, as in the world at large, a wide-spread interest in science, both pure and applied. During the war we had to turn to science for help. There was scarcely any branch of science from astronomy to geology, from meteorology to psychology that was not called upon to solve the problems that arose. Our university professors were enlisted in the cause, and they rendered invaluable service. Never before has science had such an opportunity to demonstrate its worth, and the demonstration it gave has converted the general public from an attitude of mild contempt to one of deepest respect.

Even before we were directly involved in the war, the sudden cutting off of supplies from Germany made us realize that our only road to real independence lay in enlisting the help of science to show us how to make with our own hands the products which we had previously bought from foreign countries. As a consequence, there is a wide and growing demand for research in all fields of technology. Furthermore, the public has been educated to the necessity of keeping posted on the progress of science. Engineers, manufacturers, business men, all realize more fully than ever before the interrelation between various branches of technology. No longer may a man confine his reading to his own class or technical journals. He must keep track of the march of science in contiguous and apparently remote fields.

To meet this need, we have determined to supplant the SCIENTIFIC AMERICAN SUPPLEMENT with a new journal much broadened in scope. The news that is of immediate importance which often receives erroneous or superficial treatment in the daily press is amply supplied in the weekly SCIENTIFIC AMERICAN and so it seems eminently fitting that the more serious or larger articles which are worthy of publication should be treated of in a *monthly* journal. Hence we are publishing the new journal as a monthly magazine of ninety-six text pages which will give us ample room for all the new features we wish to include. The SCIENTIFIC AMERICAN MONTHLY is naturally a distinct publication from the weekly SCIENTIFIC AMERICAN, but at the same time it will be closely allied with that journal. Many important topics which, owing to the limitations of space can be referred to only briefly in the latter, will be published in full in the monthly journal, thus making the new journal a most important if not an absolutely indispensable adjunct to the SCIENTIFIC AMERICAN.

We shall continue our policy of publishing the more important announcements of distinguished scientists appearing in foreign as well as domestic publications, thereby reflecting the most advanced thought in science and technology throughout the world. In these columns will be found the complete text of significant European articles, furnishing, often, the only translation of these papers obtainable.

In order to keep our readers abreast of the times, we have arranged with the American Society of Mechanical Engineers and also with the American Institute of Mining and Metallurgical Engineers to supply us each month with summaries of the more important articles and papers dealing with their respective fields of technology. In each case the source of the article will be given so that the reader may study the complete original text if he so desires. In a similar manner the fields of applied chemistry and electricity are covered by digests of the more important articles appearing in the chemical and electrical journals. This feature of the SCIENTIFIC AMERICAN MONTHLY will be invaluable to a wide circle of readers and especially to progressive manufacturers.

We wish to call particular attention to the department devoted to the work of the National Research Council. This department will be used as an *official organ* of the National Research Council to keep the public informed of the work that the Council is doing in organizing scientific research and introducing it into our industries. It is one of the aims of the Council to make science as important an adjunct of manufacture in this country as it is in Germany.

We are endeavoring in every way to make the SCIENTIFIC AMERICAN MONTHLY a most useful journal for the manufacturer and an interesting one for the general reader as well. For this reason, we are including in our columns the recent advances in pure as well as applied science. We shall welcome constructive criticism from any of our readers.—EDITOR.

Improvised Orthopedic Exercising Apparatus*

Specialized Corrective Gymnastic Exercises for Soldiers and Recruits

Rudolph S. Reich, M.D., Captain, M. C., U. S. Army, Fort Sheridan, Ill.

DURING June, 1918, at Camp Cody, New Mexico, the camp orthopedic staff was confronted with the necessity of carrying out on a large scale, many specialized corrective gymnastic exercises for soldiers and recruits among whom were found all of the whole gamut of orthopedic defects: weak feet; contractures of the finger, wrist and larger joints; limitation of motion of various joints incident to recent fractures, etc. For this work, the medical department provided the orthopedic staff absolutely nothing in the way of ready-made orthopedic apparatus, such as Zander machines, and at that time the principles of vocational reconstruction had not made such appliances available. The schedule of gymnastics included specialized calisthenic exercise without apparatus, supplemented by a general daily routine suited to the individual needs of the men. Although excellent results were secured, it seemed to me that the end results might be augmented by the employment of apparatus designed to assist in corrective and developmental work.

APPARATUS FOR THE LOWER EXTREMITY

Realizing the need of apparatus to facilitate flexion and extension of the foot and knee, we devised wooden steps, having a rise of 6 inches and a tread of the same dimension, arranged in such a way that the patient walked up four and down the same number. Wooden hurdles, 8 inches high, were made (Fig. 1). These were placed at variable distances, and each man stepped over them in such a way that his foot passed directly over the hurdle, necessitating flexion and extension at the knee, and extension of the foot.

The success of this simple device, which was no doubt partly due to its novelty, encouraged us in attempting other appliances. We tried to procure an old sewing machine to stimulate dorsal and plantar flexion by pedaling, but were unable to do so, and decided to build its equivalent. Through the courtesy of the reclamation and conservation officer, we obtained a fly-wheel of a washing machine. Short pieces of various sizes of lumber were obtained through the courtesy of the construction quartermaster. A frame, 36 inches high and 24 inches square (Fig. 2), was constructed out of two-by-fours. An offset was attached to the right side, and in the inside of the frame, to which was attached the fly-wheel, 24 inches in diameter. The foot-pedal, which was the chief mechanical feature, made of 2 by 10 lumber, rested on an elevation from the base, which was similar to that of a sewing machine, and it was joined to the fly-wheel by means of a wooden connection rod. The patient's seat was built to the frame, and his feet were strapped to the pedal. The efforts to force the fly-wheel gave the desired dorsal and plantar flexion with resistance, which was graduated by an adjustable brake.

Another machine, similar to the one described, was constructed, in which the pedal was hinged to the frame in such a way as to bring the fulcrum at the far end of the pedal, and in this way a wider range of dorsal and plantar flexion was obtained.

The Red Cross obtained for us an old bicycle, which included the frame, saddle, sprocket, chain, and rear axle and gear only. This was fixed upright on the floor by means of a wooden frame. (Fig. 3), and a rear wheel was constructed entirely of wood. Pedals, which were 10 inches long, also had to be improvised of wood. The feet were strapped to them, and, by putting the pedals into motion, flexion and extension of the hips and knees, as well as dorsal and plantar flexion, were obtained. Resistance was graduated as in the other apparatus, by means of a brake.

For patients afflicted with weak feet, with abduction and pronation, we used boards (Fig. 4) on which men received systematic exercises in their bare feet. Short strips of 2 by 10 lumber, 12 inches long, were cut down into double inclined planes of 120 degrees, with the apexes upward. The distal end of the board was cut to a point forming an angle of 120 degrees, and this point was notched out into a semicircle. In this way, dorsal and plantar flexion were easily obtained from the metatarsophalangeal joint, when the man sood on the board with his feet parallel and 3 inches apart, and his toes over the distal end of the board, while the incline placed the feet in adduction and supination.

For the same purpose, a long runway was constructed in the shape of a double inclined plane, with the apex pointing upward at an angle of 120 degrees, and the men were instructed to walk along this incline with feet parallel, or toeing slightly inward.

*Read before the Section on Orthopedic Surgery at the Seventieth Annual Session of the American Medical Association.

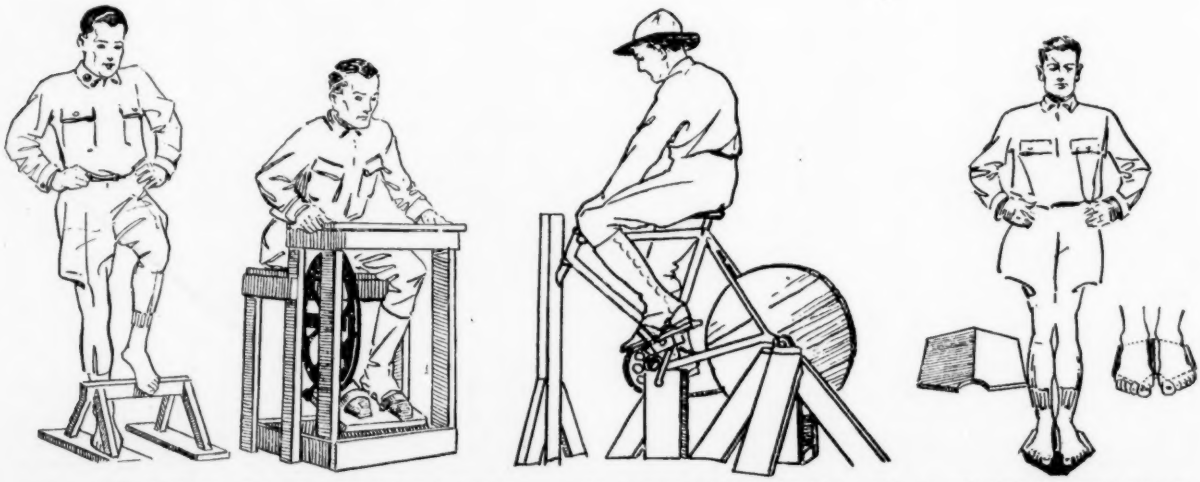


FIG. 1. THE HURDLE FIG. 2. PEDALING MACHINE FIG. 3. THE DUMMY BICYCLE FIG. 4. FOOT-EXERCISING BOARD
SOME IMPROVISED APPARATUS FOR EXERCISING THE ANKLE AND KNEE

FIG. 5. A WASHING MACHINE FLY-WHEEL AS A SHOULDER CIRCUMDUCTION MACHINE

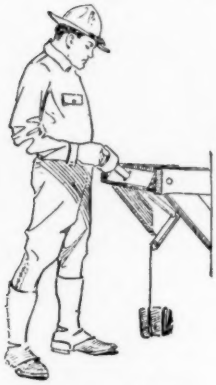


FIG. 6. PRONATION AND SUPENATION APPARATUS

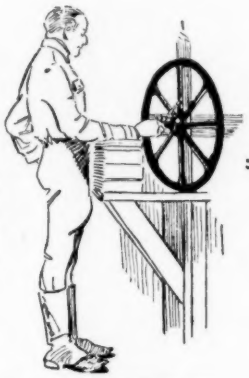


FIG. 7. WRIST CIRCUMDUCTION APPARATUS

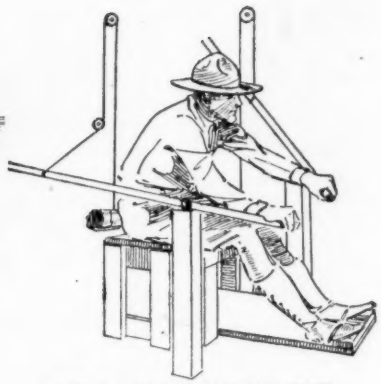


FIG. 8. AN IMPROVISED ROWING MACHINE USED FOR GENERAL EXERCISE

APPARATUS FOR THE UPPER EXTREMITY

In considering apparatus for the upper extremity, we first attempted to construct exercisers. The available materials consisted of discarded pulleys, rope and old shell casings filled with sand for weights. Handles were made from broom sticks and No. 6 galvanized iron wire. Three types were constructed: The first in which the pull was from above downward and required only two pulleys, firmly attached to the ceiling, over which the rope was suspended with the weights and handles on either side. The second, in which the pull was on a horizontal plane and required four pulleys. The first two were attached to the wall, 4 feet from the floor, and 2 feet apart. The second two were suspended from the wall 3 feet above and 6 inches to the outside of the vertical plane of the lower pair. The rope extended from the handles through the lower set of pulleys, then through the upper set, and to the shell casings. In the third type, the pull was from below upward, and also required four pulleys. The first two pulleys were attached to the floor at the junction of the wall and 3 feet apart, and the second two were attached to the wall 6 feet above and 6 inches to the outside of the vertical plane of the lower ones. From the handles, the rope extended first through the lower set of pulleys, then through the upper set, and finally to the weights.

For exercising the deltoid muscle and for producing circumduction of the shoulder joint, we employed a large fly-wheel, 30 inches in diameter, salvaged from a washing machine (Fig. 5). This wheel revolved on an axle which was fixed at one end to a metal bracket, a part of the original washing machine. It was mounted on a wooden offset 5 feet from the floor, and in such a way that the axle projected horizontally at right angles to the wall. A wooden handle was inserted into the rim, and a wooden brake was applied against the rim, the pressure being regulated to suit the needs of the patients.

An apparatus for pronation and supination exercise of the forearm was thus constructed: A piece of two-by-four about 20 inches long was trimmed down at each end to leave two cylindric projections like the handles of a rolling-pin (Fig. 6). It was mounted on a pair of wooden brackets fastened to the wall, 30 inches from the floor, in a position similar to that for a roller towel rack, and was then perforated in the center at right angles to its long axis, a hole being made of the right size to receive snugly the shaft of a sawed-off shovel handle, which was pushed through it with the handle on its near side, and the shaft projecting toward the wall. Two wooden pins driven through the shovel handle, one on either side of the crosspiece, fixed the shovel handle in this position without preventing its free rotation in the hole. At the distal end of the shovel handle and at right angles to it, there was attached a stout lever arm 6 inches long, and from this a weight was suspended. Whereas this machine was devised merely for pronation and supination exercisces by rotating the shovel handle, the roller bearing permitted an adjustment for the height of the man.

We constructed another appliance, similar in every detail to the pronation and supination machine, with the exception that the shaft of the shovel handle moved in a large oval opening, thus giving the handle a wider range of movement.

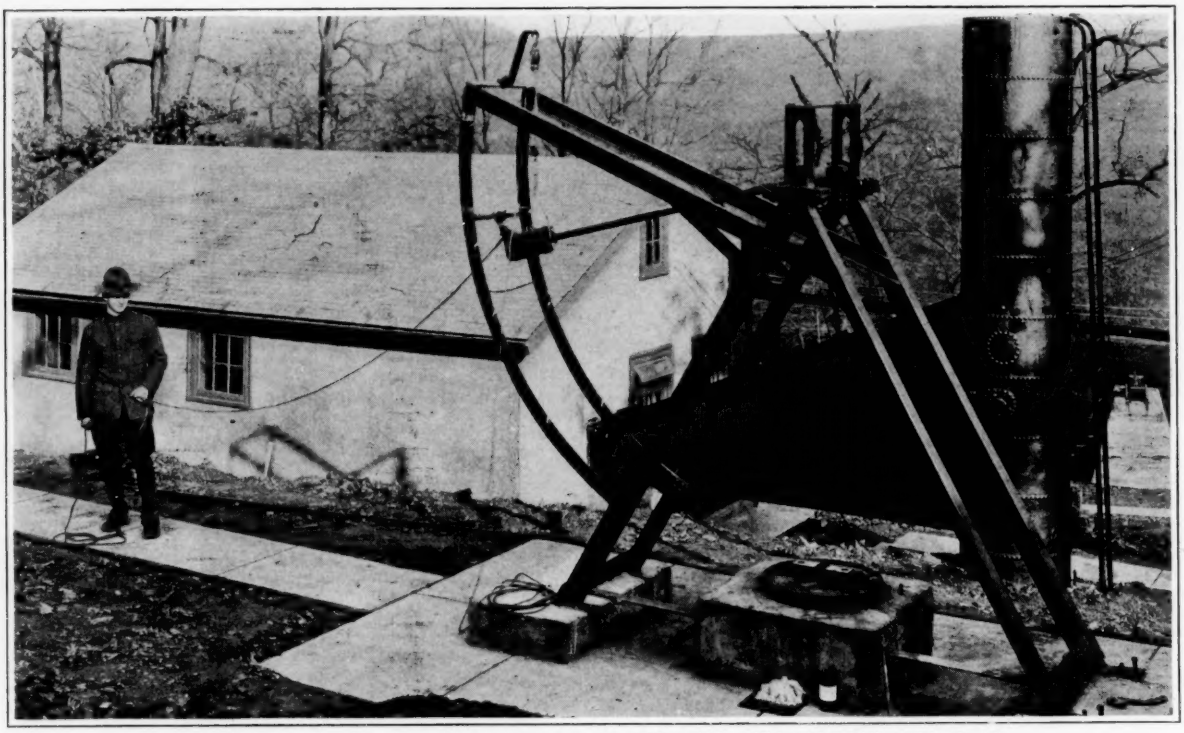
To produce circumduction at the wrist, we mounted a wheel with its axle on a wooden bracket in the same position as the wheel in the shoulder circumduction apparatus, with the exception that the axle was 3 feet high (Fig. 7). The wheel was 12 inches in diameter, and it also was obtained from the reclamation department. A wooden arm support was mounted on a level, with the axle, at right angles to the plane of the wheel, and 12 inches away from it. The arm was fixed to the support by means of straps in such a position that the carpometacarpal joint rested on the edge of the support. The patient grasped a discarded screw driven in his hand, and placing the shaft between the spokes, propelled the wheel. Thus, the desired circumduction was obtained.

APPARATUS FOR GENERAL EXERCISE

For the purpose of obtaining general exercise, a rowing machine was suggested. Two uprights were built to the floor out of two-by-fours 30 inches high, 4 feet apart and 4 feet from the wall. (Fig. 8). Oars were constructed out of two-by-fours, 3 feet long, the ends of which were whittled down for handles. The oars were pivoted to the uprights through their centers by means of discarded motor valve stems. Two pulleys were fastened to the wall at the same height and immediately behind the distal ends of the oars, and two more placed 3 feet above and 6 inches outside of the vertical planes of the lower set. Ropes were tied to the distal ends of the oars and extended through the lower pair of pulleys then through the upper pair to the two shell casings filled with clay as weights. A seat was mounted behind the oars with three footrails in front. Four rollers attached to the bottom of the seat permitted free backward and forward motion on a wooden track. The novelty of this device proved to be quite attractive to the men, and they took great advantage of it.

COMMENT.

The purpose of this brief review of the practical application of well-known scientific principles in the crude apparatus devised will be served if I have been albe to demonstrate the early approach thereby to the larger field which concerns us now as orthopedic surgeons, namely, the application of the principles of vocational training and re-education to the wounded soldiers returning to our reconstruction hospitals. It is believed that the success attained in the service at Camp Cody will be encouraging to those who may be called on to make an effort at rehabilitation in centers where modern means of vocational training may not be readily available.



ABOUT TO RELEASE THE SWINGING SHOE OF THE PENDULUM FRICTION APPARATUS

A Pendulum-Type Testing Apparatus*

Testing Potassium Chlorate Explosives at the U. S. Bureau of Mines

By S. P. Howell

IT has long been known that many commercial explosives may be exploded by severe and prolonged friction. It is also well established that some explosives are more sensitive to friction than others.

Certain kinds of potassium chlorate explosives have long been regarded as very sensitive to friction, as evidenced by the following quotations from Berthelot, Gody, Dupré, and Brunswig. Berthelot says:[1]

"Berthollet, after having discovered potassium chlorate and recognized the oxidizing properties so characteristic of this salt, thought of utilizing it in the manufacture of service powders. He made several attempts in this direction, but immediately suspended them after an explosion which happened during the manufacture carried on at the Essonnes powder factory—an explosion in which several persons were killed around himself. The same attempt has been revived at various periods, with certain variations in the composition.

"But in every case explosions, followed by loss of lives—such, for instance, as those which happened during the siege of Paris in 1870 and at L'Ecole de Pyrotechnie in 1877—happened before long in the course of its manufacture.

"It is thus clear that potassium chlorate is an extremely dangerous substance, which is only natural, because its mixture with combustible bodies is sensitive to the least shock or friction."

Gody says:[2]

"Berthollet missed losing his sight from the explosion of a chlorate explosive during imprudent manufacture in a mortar. . . .

"The mixture of combustible material with potassium chlorate must be made with the minutest precautions, as the least shock or friction may cause an explosion."

Dr. Dupré, as cited by De Kalb,[3] says:

"Chlorate of potassium, on account of the readiness with which it lends itself to the production of powerful explosives, offers a great temptation to inventors of new explosives, and many attempts have been made to put it to practical use, but so far with very limited success. This is chiefly owing to two causes. In the first place, potassium chlorate is a very unstable compound and is liable to suffer decomposition under a variety of circumstances, and under comparatively slight causes, chemical and mechanical. All chlorate mixtures are liable to what is termed spontaneous ignition or explosion in the presence of a variety of materials, more particularly of such as are acid, or are liable to generate acid; and all chlorate mixtures are readily exploded by percussion, such as a glancing blow which might easily and would often occur in charging a hole. In the second place, there is some evidence to show that the sensitiveness to percussion and friction increases by keeping, more especially if the explosive is exposed to the action of moist and dry air alternately."

Brunswig,[4] a more recent authority, in speaking of chlorate powders says:

"These powders have received little attention on account of

*Technical Paper 234, U. S. Bureau of Mines.

[1]Berthelot, M.P.E., Explosives and their power, translated by C. N. Hake and William Macnab, 1892, p. 518.

[2]Gody, L., Traité théorique et pratique des matières explosives, 3rd ed., 1907, p. 240.

[3]De Kalb, Courtenay, Manual of explosives, 1900, p. 16.

[4]Brunswig, H., Explosives, translated and annotated by C. E. Munroe and A. L. Kibler, 1912, p. 302.

their greater sensitiveness toward shock and friction. In more recent times, however, the preparation of chlorates and perchlorates by electrical methods has made these substances easy to obtain, and it has been discovered that the addition of fatty oils to chlorate mixtures decreases their sensitiveness.

"Various annual reports[5] of His Majesty's inspectors of explosives, Great Britain, record fires and explosions with various potassium chlorate explosives during the operation of sifting, mixing, ramming with wooden rammers, and ramming with bronze rammers."

A certain potassium chlorate explosive that is used in the United States and is designated "Chlorate explosive B" in this paper has come under suspicion because of premature explosions that occurred while it was used in bituminous coal mines. The details of these accidents are as follows:

1. While inserting copper needle in a charge in a tamped bore hole the charge exploded. Miner not injured.

2. This accident occurred less than one hour after accident 1, but in another room of the mine. The charge exploded while the copper needle was being inserted in the charge in a bore hole. Miner not injured.

3. While pushing a 12-inch cartridge into bore hole, with copper needle inserted about 6 inches in it, and just before charge reached back of bore hole, the charge exploded. Miner severely burned and hand badly lacerated.

Other potassium chlorate explosives containing potassium chlorate and sugar also exploded prematurely in coal mines in the United States. The details are as follows:

4. A 7-inch by 1-inch charge had misfired in a 5½-foot bore hole, presumably on account of using wet squibs. The stemming was then drilled out about 3 feet and copper needle inserted to reform the needle hole. The needle went into the clay stemming easily and the miner "did not have to exert any strength to force it." He was turning the needle around to form the hole for the squib and just as the needle went through the stemming it turned to go a little bit faster, then the shot went off prematurely. The miner lost the thumb and index finger of his left hand, besides being lacerated about the chest and arms, and his face was slightly cut.

5. While a miner was tamping several inches of stemming on the explosive it exploded. No injury reported.

6. After putting in several handfuls of stemming on the explosive it exploded. The cartridge had been broken when being inserted. No injury reported.

7. Exploded while pushing the copper needle into the explosive. No injury reported.

In view of the frequency of these accidents and the seeming ease with which they took place, not being explanable by the sensitiveness of the explosive itself to friction, it was considered advisable to determine, if possible, the cause of the excessive sensitiveness to friction.

As the coal in the mines in which these accidents occurred contains pyrite-bearing bands, it was thought that the pyrite might be a general cause of the accidents, as practically all bituminous coals, and especially those of the Middle West have these pyritiferous bands.

At the suggestion of Clarence Hall, chief explosives engineer of the Bureau of Mines, the experiments described below were made to determine the effect of pyrite-bearing coal on sensitiveness to friction of potassium chlorate explosives.

Chlorate explosive B, which failed to pass the pendulum friction test with the wood-fiber shoe dropped from the 1½-meter position, gave no unfavorable results in 10 trials when the wood-fiber shoe was dropped from the 1-meter position. Under the same conditions, but mixed with small pieces of pyrite-bearing bituminous coal, the explosive ignited in each trial. It was found also that ignition occurred when the height of fall was reduced to ½ meter and even to ¼ meter.

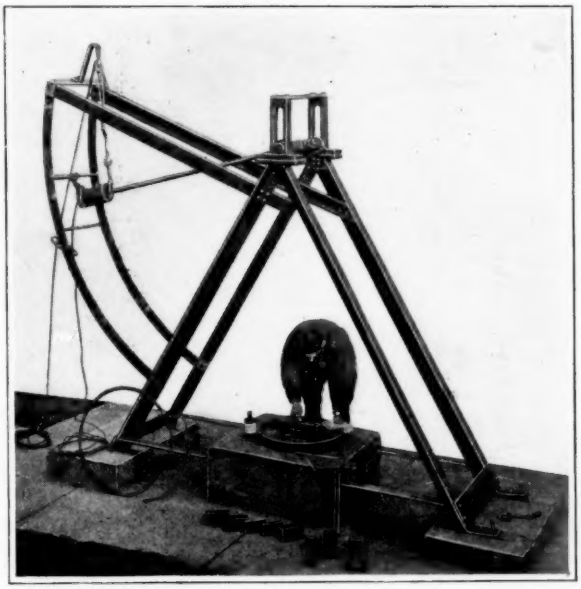
Similar tests made with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignitions.

In order to determine whether the friction of a moving copper-wire needle in a bore hole would be sufficient to cause an ignition of chlorate explosive B, the following test was made.

A hole one-half inch in diameter and 4 inches deep was drilled in a block of bituminous coal. A 2-gram charge consisting of 4 parts of chlorate explosive B, 1 part coal dust, and 1 part pyrite of the same granulation as the explosive was placed in the bore hole. The friction from the movement of a No. 8 (B. & S. gage) copper needle within this mixture caused ignition.

Repeated with three other chlorate explosives of the same general type, this test gave the same results.

Similar tests with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignition.



PREPARING FOR A TEST WITH THE PENDULUM DEVICE

An unpublished report by Russell B. and Treadway B. Munroe, which was available to the Bureau of Mines, on the effect of metallic sulphides on a sodium chlorate explosive showed that both antimony and lead sulphides increased the sensitiveness of the explosive to friction more than pyrite.

This conclusion is in part corroborated by the work of Cushman,[6] who shows that in priming compositions the compositions containing antimony or lead sulphides are more sensitive to impact than the composition containing pyrite.

To determine the sensitiveness of potassium chlorate explosives, the English have long used the broomstick test. This test consists in spreading a small quantity of the explosive on a soft wood surface and striking it a glancing blow with a broomstick. An explosive is considered as having passed this test if it fails to explode or crack when tested repeatedly.

A rawhide-mallet test has been used at the Bureau of Mines and elsewhere to determine the sensitiveness of explosives. A small portion of the explosive is spread on a smooth oak surface and struck a glancing blow with the mallet. The explosive is considered as having passed this test if there is no explosion or local crackling.

Obviously the broomstick test and the rawhide-mallet test lack the uniformity in execution that should characterize a scientific friction test, so in June, 1911, the Bureau of Mines

[5] 32d annual report, 1907, pp. 114, 122; 33d annual report, 1908, p. 95; 34th annual report, 1909, p. 104; 36th annual report, 1911, p. 109.

[6] Cushman, A. S., Antimony sulphide as a constituent in military and sporting arms primers; *Jour. Ind. and Eng. Chem.*, vol. 10, 1918, p. 376.

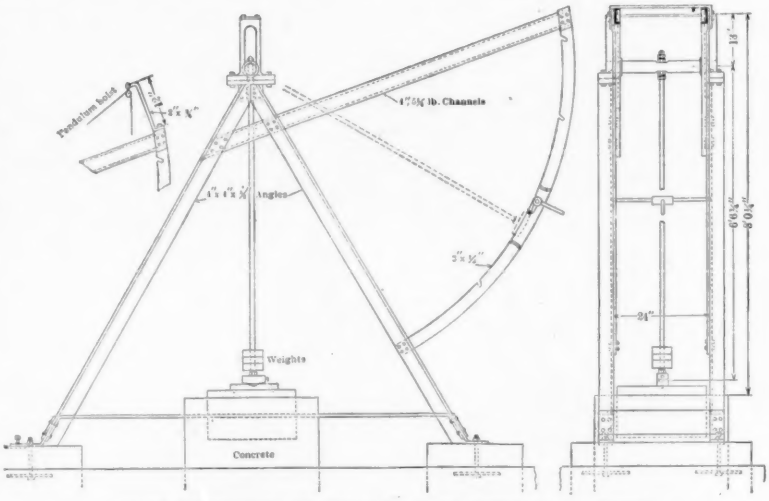
designed a pendulum friction device. The first tests with it were made in September, 1911. Tests of a variety of explosives, including permissible explosives, commercial explosives other than permissibles, black blasting powder, and potassium chlorate explosives, showed that all explosives except a certain potassium chlorate explosive passed the test.

In October, 1911, a committee consisting of Dr. C. E. Munroe, C. P. Beistle, and Clarence Hall was appointed to pass upon the propriety of the pendulum friction test as a requirement for determining the permissibility of explosives for use in coal mines.

After studying the results of the preliminary tests, and witnessing tests of the pendulum friction device provided with a wood-fiber shoe, the committee recommended the adoption of the test. Their report was approved by Director J. A. Holmes on November 22, 1911.

In the opinion of the director and the committee, the failure of an explosive to pass the pendulum friction test as adopted by the Bureau of Mines should be considered an unfavorable physical characteristic because of the liability of such an explosive to explode in drill holes, by such friction as may be produced by a tamping rod. Moreover, they decided that the Bureau of Mines was not warranted in placing on the permissible list any explosive that failed to pass the pendulum friction test, but did pass other required tests.

The pendulum friction device adopted by the Bureau of Mines comprises a steel anvil and a swinging shoe. The anvil has a smooth face, 3.25 inches (8.3 cm.) wide by 12 inches (30.5 cm.) long, in the middle of which are three grooves for holding the charge of explosive. The shoe is 3¼ inches (8.3 cm.) wide, its radius of swing is 6 feet 6.75 inches (2 meters), and the radius of curvature of its face is 10.5 inches (26.7 cm.). The shoe may be of steel, or of steel faced with hardwood fiber or other material, and may be dropped from heights up to 78.7 inches (2 meters). Added weights of 2.2 to 44 pounds (1 to 20 kg.) may be used.



ELEVATION AND DETAILS OF THE TESTING MACHINE

In the official test adopted by the Bureau of Mines a steel shoe faced with hardwood fiber, 44 pounds (20 kg.) added weight and a fall of 59.1 inches (1.5 meters) are used. The shoe is squarely adjusted so that when there is no explosive on the anvil it will swing across the face of the anvil 18±1 times before coming to rest.

In making the test 7 grams of the explosive is spread in an even layer in and above the three grooves in the anvil. Each test consists of 10 trials. After each trial the remaining explosive is brushed from the anvil and shoe, and both are thoroughly cleaned with a solvent to insure the complete removal of the explosive. When the steel shoe is used, both the shoe and anvil after each trial are rubbed with carborundum cloth to remove any roughness caused by the preceding trial; thus any gritty material is thoroughly removed.

The usual tests are made at normal temperatures (14° C. to 30° C.), the temperature of the anvil and of the shoe being controlled.

The observations made are explosion, whether complete or partial; burning; local crackling, whether distinctly audible or almost indistinguishable; and no local crackling. An explosive that gives no more unfavorable result than an almost indistinguishable local crackling with the wood-fiber shoe is considered as having passed the test.

As soon as tests showed that the steel shoe was more severe than the wood-fiber shoe, explosives were first tested with the steel shoe and usually were not tested on the wood-fiber shoe if they passed the test with the steel shoe. (*The Bulletin contains a number of tables which are omitted.*—EDITOR.)

SUMMARY OF RESULTS.

1. Tests with the steel shoe are much more severe than tests with the wood-fiber shoe.

Forty per cent straight dynamite passed the test at 2.0 meters fall and 20 kilograms added weight with the wood-fiber shoe, but failed with the steel shoe at 0.5 meters fall and 20.0 kilograms added weight, and 1.5 meters fall with no added weight. Moreover, the record shows that 40 explosives failed under test with the steel shoe but passed the test with the wood-fiber shoe, but for no explosive was the reverse true.

2. All the explosives tested with the wood-fiber shoe passed the test except 10 potassium - chlorate explosives and one perchlorate explosive.

3. Of 267 samples tested with the steel shoe, 55 failed to pass the test.

4. Black blasting and ignition powders, blasting gelatin, ammonia dynamites, and organic nitrate explosives (other than nitroglycerin) are not as sensitive to frictional impact as the nitroglycerin dynamites and the gelatin dynamites.

5. TNA, tetryl, 50/50 amatol, and 60/40 sodatol are more sensitive to frictional impact than TNT, picric acid, ammonium picrate, 85/15 amatol, 80/20 sodatol.

6. Tests of TNA, and of 40 per cent straight dynamite with the steel shoe, show that increasing the height of fall increases the severity of the test.

7. Tests of 40 per cent straight dynamite with the steel shoe show that decreasing the added weight decreases the severity of the test.

8. The tests at normal and high temperatures showed that no discrimination can be made on the basis of increasing the temperature.

9. Potassium chlorate explosives have proved extremely sensitive to frictional impact even when the wood-fiber shoe is used. But some were rendered sufficiently insensitive to friction by adding an adequate quantity of mineral oil, vegetable oils, and aromatic nitro compounds.

10. That the pendulum friction device, as adopted by the Bureau of Mines, is not too severe is indicated by the fact that one of the potassium chlorate explosives which passed the test has on more than one occasion exploded prematurely during manufacture and use. On the other hand, potassium chlorate explosives of the general type of E (potassium chlorate, sugar and gum arabic) which failed to pass the pendulum friction test exploded prematurely on several occasions in use.

11. The sensitiveness of potassium chlorate explosives to friction is increased by the presence of pyrite-bearing coal.

Luminous Living Creatures*

The Mystery of "Cold Light"

By Dr. Raphael Dubois, Prof. of General Physiology, University of Lyons

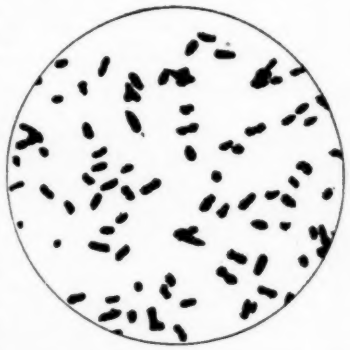
LIVING creatures produce not only motion, heat, and electricity but also light, more or less vital in character, and the glow worm with which all the world is familiar has by no means a monopoly of this manufacture.

In every part of the globe, in the air, in the woods and meadows, in the bosom of the waters, there are living signal lights gleaming with strange and shimmering fires, which are incomparably beautiful and suggestive, not only in the eyes of the poet but even more so in those of the savant, for the scientific researches which have been undertaken in the hope of plucking from nature this marvellous secret of hers are numbered by thousands. Upon the surface of the ocean, sometimes over immense extents, the sea shines with a splendor that rivals the starry firmament, while in the depth of its abysses fairy illuminations suddenly blaze forth among the forests of polyps at the passage of fantastic animals, which are themselves wreathed with shining gems, the strange brilliance of whose fires would put to shame the most sumptuous jewels.

Plants also produce light. In the gloomy galleries through which the miner, ever on his guard against the deadly fire damp, bears his dim and dangerous candle, the myceliums of fungi shine upon old worm eaten beams with a calm, pale, harmless, moonlight gleam. It is these vegetative organs of fungi, also, which in the forests produce the phosphorescence of dead wood and leaves and old stumps. Adult fungi, such as the Agaric of the olive, which is common in Provence, likewise shine in the dark. In Brazil and in Australia the emerald green light of other species is so bright that one can easily read a newspaper or see the time on a watch dial by means of this living torch.

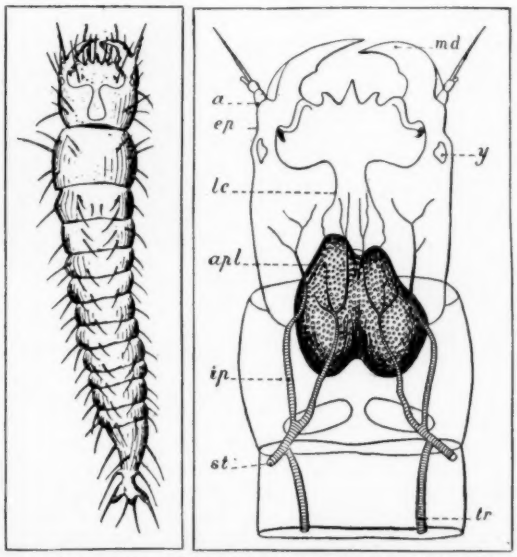
Most extraordinary are those infinitely small fungi, the luminous microbes or Photobacteria. Some thirty species of marine origin are known. They are particularly abundant in the mucus of the skin of sea fishes, but their phosphorescence does not develop, however, until from twenty-four to forty-eight hours after the animal has been taken from the water. It is readily communicated by microbian contagion to butchers' meat. The latter often becomes luminous when it is merely exposed to the air after having been moistened with salt water. The phosphorescence is continuous but is scarcely visible except at night when the eye is rested from the light of day. The first phosphorescent microbe of meat which has been isolated and cultivated in the pure state is that to which I have given the name of *Photobacterium, sarcophilum.* The ingestion of these microbes is not at all dangerous; the frog can never be inoculated with them with impunity, as I long ago demonstrated. The same thing is not true, however, of certain small crustaceans (shrimp, prawns, sea fleas, wood lice), which become entirely luminous after inoculation but soon perish. Gnats and mosquitos sometimes exhibit this luminous malady spontaneously and it might be possible to attempt to destroy by this means these creatures which propagate harmful germs like that of malaria.

I have found non-pathogenic luminous microbes in the interior of the organs of certain animals which are themselves phosphorescent. However, those persons who pretend that these are normal or *symbiotic* microbes which produce physiological animal light have incorrectly interpreted my observations. A very curious circumstance, however, is that when inoculating with photobacteria gelatinous bouillons containing lecithine I have provoked the formation of luminous cells much resembling those of the glow worm in certain respects. They are formed by the agglomeration of a multitude of photobacteria which have lost their bacterial form and become transformed into very small micrococci. The photobacteria are very polymorphous and very polybiotic, which has led some authorities to multiply the species without justification. There are some forms which are immobile and others which move by means of propulsive cilia. In their internal structures these forms resemble the *vacuolids* or microleucites which I have described as being the most simple general form of living substance or *bioproteon.*



A GROUP OF PHOTOBACTERIA OR LUMINOUS MICROBES

The luminous microbes are easily cultivated in liquid or gelatinous nutritious bouillon containing three per cent of salt, by coating the inside wall of large, sterilized glass casks with gelatinous bouillon which had been planted with selected photobacteria, I was enabled in 1900, at the International Exposition of Paris, to illuminate as with the most beautiful moonlight the underground chambers of the Palace of Optics. It was upon the same principle that I constructed my *living lamp.* This is composed of a convex glass vessel whose silvered dome serves as a reflector and into which filtered air passes through cotton wool inside of two aeration tubes. With this little night lamp which will last a month without going out and without consuming more than two cents worth of fuel, one can easily read in the dark or distinguish the objects in a room. Moreover, it is very portable and cannot set anything on fire since it radiates only *cold light.* Unhappily I have not as yet been able to impart sufficient intensity to this method of illumination. At the present time this lamp has scarcely any possible practical ap-

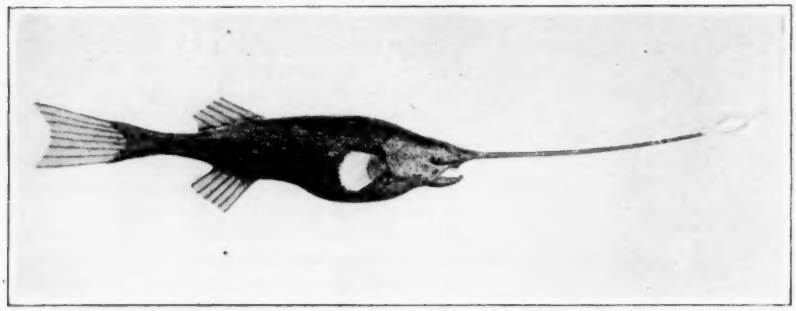


LARVA OF *PYROPHORA NOCTILUCA* AND ITS LUMINOUS APPARATUS

Md. = mandibles; *a* = antennae; ep = epistome *y* = eye; *le* = clear line; *apl* = apparatus producing light; *ip* = insertion of first pair of legs; *st* = level of first stigmata; *tr* = trachea.

*Translated from *Science et La Vie* (Paris).

plication except in powder mills in mines where fire damp is feared, or as a night lamp in those hot countries where even the gentle heat from an incandescent electric light is annoying. The light of this lamp is more feeble than that of the illuminating apparatus of insects, of cephalopods, or of certain fishes, in spite of the fact that it is a result of the same reaction; but the luminous organs of these animals are provided with improvements which greatly augment their brilliance. When these organs are crushed they do not shine, unfortunately, with any more brilliance than do the microbes.



MODEL OF THE *GIGANTACTIS VANHOEFFENI*, A DEEP SEA FISH WHICH CARRIES A LUMINOUS TORCH AS A LURE TO ITS PREY

Luminous animals are found in almost every degree of the zoölogical scale from the Noctiluca, the microscopic infusoria which produce the magnificent and impressive spectacle of the phosphorescent sea, up to and including the vertebrates. In the bosom of the ocean numerous photogenic Coelentera undulate gracefully like animated flowers made of the purest crystal—Medusas, the cestus or girdle of Venus, the Physalia with their numerous fishing tackle, while upon the surface there float flotillas of light Velellae with their triangular sails, etc., etc.

Upon the bottom of the sea and even at the bottom of the abysses there grow the Polypidae, actual luminous shrubs whereupon the polyps resemble gleaming flowers with changing colors which glow with light at the slightest touch.

Then there are the starfish, like the Brisinga which derive their appellation from "Brising," the name of the sparkling jewel which rested upon the bosom of Freia, the goddess of love and beauty in Scandinavian mythology. Quite close at hand in our own gardens we often see at night time the earth worms and the "thousand legs" leaving behind them trails of phosphorescent mucus, and in south Germany I have seen the ground sprinkled with shining sparks like the sand of our beaches, thanks to the presence of the little *Lipuris noctiluca*. But it would require a volume to describe all these curious shining animals, for they are legion.

Among the crustaceans, the Cephalopod mollusks, and the fishes the luminous organs are often situated near the eyes or around them in such a manner as to illuminate clearly the objects which they desire to see. They are then provided with lenses, reflectors, screens, etc., which make of them perfected lanterns called "photospheres."

Although less complicated than these photospheres the lanterns of the insects are very brilliant. That of the female glow worm can be distinguished for a long distance. But nothing can equal in power and in beauty the signal lights of the Pyrophora of the Antilles. This sturdy and magnificent *taupin* possesses three of these—two upon the corselet and one underneath the abdomen. It makes use of the first two when walking, of the third when swimming, and of all three at the same time when flying. These beautiful insects produce a very strikinng effect when they fly along the edge of the woods or sugar cane plantations in the eveninng. One of them which arrived at Paris with some wood from these islands in September, 1766, produced quite a little revolution in the Faubourg St. Antoine, where it was taken for a shooting star! The author of *The History of the French Antilles* (*Histoire des Antilles française*) P. Dutertre, wrote in 1667: "They are like little animated stars which in the darkest nights fill the air with an infinity of beautiful lights which shine and gleam with more brilliance than the stars in the heavens. . . . These little candles often relieve the poverty of our good fathers who lack both oil and candles for the greater part of the year. When they are thus reduced each of them grasps one of these shining flies and reads his matins with as much ease as if he had a candle." Then he adds further: "If these flies were incorruptible like precious stones and could retain their light it is certain that diamonds and rubies would lose their value." It is not astonishing, therefore, that the beautiful Mexican ladies keep these little creatures captive to make of them living adornments.

When the New World was discovered the Indians enclosed them in perforated gourds hung in their cabins, both to light them by night and to drive away snakes and mosquitos. In time of war they made use of these signals which are extinguished neither by rain nor wind to carry on a sort of optical telegraphy, of which art they are thus the real inventors. It was these sturdy coleopetera, of which I received a number of living specimens from Guaduloupe when I was a preparer for Paul Bert at the Sorbonne, which enabled me to make a complete anatomical and physiological study, thus discovering the secret of the intimate mechanism of their curious lanterns and obtaining a definite analysis of the physical properties of their beautiful light. In the very heart of Paris I have seen them lay their luminous eggs from whence issued larvae likewise luminous, so that in the case of these extraordinary insects, as in so many other photogenic animals, phosphorescense is transmitted like the flame of life itself without ever being extinguished for a single instant from generation to generation throughout the ages.

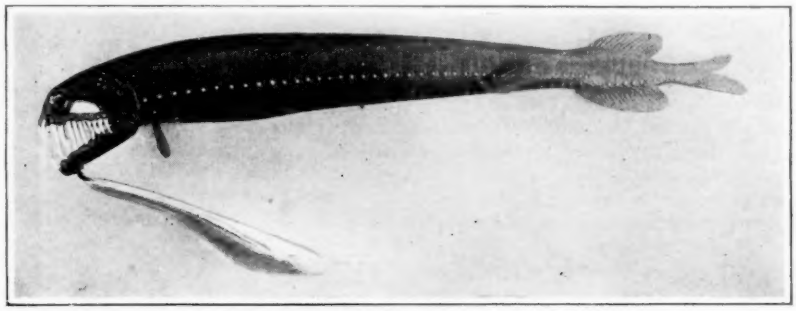
MODEL OF THE *OPISTHOPROCTUS SOLCATANUS*

The molluscs likewise afford curious specimens. The *Eunoploteuthis diadema* is a cuttle fish caught at a depth of 1,500 meters. It is provided with 24 lanterns, five of which are situated around each of the two eyes. These give forth a light of the most incomparable beauty. One might imagine the body of the animal adorned with a diadem of precious stones of varied color and of the finest water. The median points

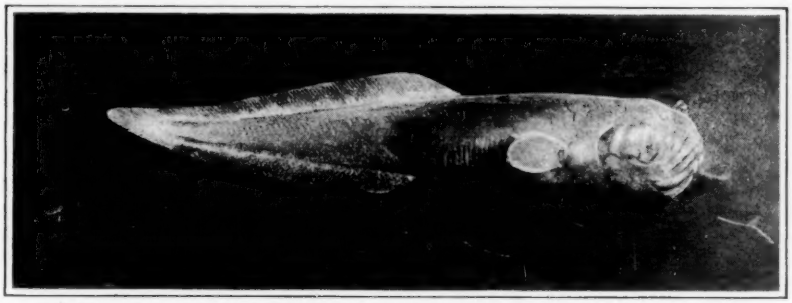
shine with an ultramarine blue, while the lateral ones show the tints of mother of pearl. The abdominal organs send forth rays of ruby red, while the posterior ones are white as snow or pearly in tint, with the exception of the median point which shines with a celestial blue. But it is only among the fishes that we find organs so highly complicated. The *Stomias* present a double row of them on each side of the body, as does the curious *Stylopthtalmus paradoxus* which also possesses lantern eyes borne upon long movable tentacles.

In the Melanocetus of the abysses the signal-light is placed at the end of a movable wattle, and probably serves as a lure to attract within the huge and well-armed jaws of the little monster the organisms upon which it commonly feeds. In other cases, as in the *Photoblepharon palpebratus*—a surface fish of the Dutch East Indies, whose fishermen utilize the luminous apparatus as bait—the signal-lights are situated below the eyes and are movable like the latter, which enables the animal to mask them whenever it so desires.

MODEL OF THE *MELANOSTOMIAS MELANOPS* STUDDED WITH LIGHTS WHICH



LOOK LIKE PORTHOLES OF A SHIP AT NIGHT



MODEL OF THE LUMINOUS DEEP SEA FISH *BARATHRONUS DIAPHANOUS*

Apparently phosphorescence does not exist among vertebrates higher in the scale than the fishes. The cases in which luminosity is exhibited by cadavers, by wounds, by sweat, by urine, and by excrement are pathological in nature and call for more extended study. In all cases of organisms which are normally luminous the photogenic organs, when they are differentiated, consists of glands, which discharge either outwardly, as in the earthworm and the wood-louse or "thousand legs," or else internally, as in the fishes, the cephalopods, and the insects, their magnificently luminous secretion.

The ventral photogenic organ of the *Pyrophorus noctilucus* is a type of the internal secretion luminous gland. It is in the form of a cushion traversed by a sinus at T. At the instant when it functions the small lateral muscles draw apart by means of traction the walls of the sinus, into which the blood at once rushes, causing the instant appearance of the light. The muscles are activated by nerves coming from certain nerve centers and it is by means of these that the reflex or voluntary contractions which control the illumination and the extinction of the light are operated. The gland is constituted of rows of cells whose disintegration yields the liquid of the luminous secretion, which, upon contact with the oxygenated blood, produces the light, by a process which will be explained further on. The trachea, which are abundant in these organs, play merely an accessory part, for they do not appear in the egg, which is luminous nevertheless, nor in the analogous apparatus of the cephalopods and the fishes. Doubtless the trachea serve here as elsewhere to aerate the blood, an especially important operation in this instance.

If the luminous organ be crushed in a little water so as to entirely destroy all trace of cells a liquid is obtained which remains luminous for a considerable length of time, but which is instantly extinguished by any physical or chemical agent capable of destroying the zymases and the proteic substances. When filtered this luminous liquid is opalescent—like all colloidal solutions—and contains very fine granulations which are termed zymasic *vacuolids*.

As early as 1886 I succeeded in demonstrating the fact that in the last analysis the luminous phenomenon results from the conflict between two substances, a zymase and a proteic substance, which exhibits, after the action of the zymase, the xantic reaction of nitrogenous organic bodies. This had to be made more definite—but Pyrophoras were lacking, and furthermore their provision of luminous substance is much too scanty for extensive chemical research. I turned my attention, therefore, to a lamellibranch Mollusc, the dactylated Pholas, which is abundant in the vincinity of the maritime laboratory of physiology founded by me at Tamaris-sur-Mer, near Toulon. The photogenic glands of this shell-fish secrete an abundance of a luminous mucus which exhibits the same reactions as the secretions of all other luminous organisms, in which the fundamental nature of the photogenic process is always the same. Not without great difficulty and repeated efforts, I was finally able to extract, isolate, and determine the chemical characteristics of two principles which I have termed respectively *luciferase* and *luciferine*. The first is an oxidizing zymase, while the second is a natural

THE *STYLOPHTHALMUS PARADOXUS* WITH LANTERNS AT THE ENDS OF TENTACLES WHICH MAY BE EXTENDED OR RETRACTED AT WILL

albuminoid. When either of these is shaken separately in contact with air and with water no light appears, but upon mingling the two aqueous solutions a very beautiful glowing light is at once produced. But if the water is saturated with sugar the two solutions can be mingled without producing light, since this condition paralyzes the action of the oxidizing zymase. The syrup can be kept quite a long time without undergoing alteration, but as soon as water is added the luminous glow appears; the glass in which the reaction takes place can be used for a night lamp. . . .

The luciferase can be replaced by various oxidizing chemical substances, a fact which clearly indicates its mode of action; among these are permanganate of potash, broxide of lead, hydrogen peroxide containing a little blood or hermatine or simply a ferric salt, etc., etc.

Synthesis follows upon analysis—the former would be complete if we could manufacture luciferine artificially. However this is not necessary to occasion the appearance of cold light in a liquid medium by means of oxidation. These phenomena of "oxyluminescence" are even quite numerous, but the most beautiful of all is that which I have obtained with esculine, a fluorescent chemical principle extracted from the chestnut tree.

Now that its principle is known, it is possible therefore to imitate "living," or rather physiological light. It must be admitted that the light obtained *in vitro* is not so powerful as that from the lantern of the Pyrophora, in spite of the fact that the chemical process involved is the same. But, as we have seen in the foregoing remarks, these insects, like the cephalopods and the fishes, possess accessories which make for improvement. One of the most curious of these is that discovered by me in 1885; it consists of the presence of a fluorescent substance in the luminous organs of the Pyrophora and of the Luciola: this is a *luciferescein* whose effect is the transformation of the dark rays, which are both useless and injurious, into illuminating rays, which superpose themselves upon the fundamental photogenic reactions, just as sonorous harmonics or overtones superpose themselves upon the fundamental note of a sound. It is in this manner that sounds acquire an agreeable *timbre*, and in the same way fluorescence imparts to the light of the Pyrophora a shimmering effect of the greatest beauty, while at the same time much augmenting its power.

It is thanks to the Pyrophora that it has been possible to make a complete and authoritative analysis of the physical properties of physiological light. Its enormous superiority over that of all other known sources of light, including the sun itself, has become a classic fact, today, and the correctness of the results already published by us has only been confirmed by the latest researches of physicists of the highest ability, such as MM. Very and Langley in America.

It is incontestably established today that this living or physiologic light may properly be called *cold light*, since the radiations emanating from the photogenic organs contain only infinitesimal amounts of heat. If we add that the actinic power of the visible and ultra-violet radiations whose presence I have demonstrated scarcely exceeds one ten-millionth part of a candle power we may claim that the work done by this marvelous lamp is almost 100 per cent, while with the most improved quartz mercury lamp not more than one per cent of light is obtained, according to the extremely exact calculations of MM. Fabry and Buisson, the rest of the energy expended being consumed in the production of heat and chemical energy, which are always inconvenient and sometimes actually injurious. Let us remind the reader also of the extremely low price of my living lamp which will light a room as with fine moonlight for a month for but two cents.

Gas with its necessary pipes and its accompanying dangers of fire and of asphyxiation, and electricity with its wires and its non-transportable apparatus, as well as our lamps and candles, are destined to disappear, since the process by which physiologic light produced is now perfectly understood and classed among the oxy-luminescences, why may we not hope that the day will come when we shall be able to imitate and even to surpass that made by natural means? We are certainly far nearer the practical solution of the problem than were Galvani and Volta at the time of their immortal discoveries.

[*We are indebted to the American Museum of Natural History for the photographs illustrating this article.*—EDITOR.]

The Effects of Light on Plants*

Light As a Catalyzer

By San. Rat Dr. Fritz Schanz

MAN has undoubtedly recognized from the very beginning that light is an essential factor in life. Light acts upon living cells as a chemical stimulus. We recognize this by the reactions which it occasions in living tissues. The chemical alterations which it thus produces have been known to us only very recently. The first insight into the effects light exerts upon the living organism was vouchsafed to us when Finsen proved that the alterations of the skin which occur when the latter is exposed to intensive light waves are produced chiefly by the rays of short wave length which the human eye is incapable of perceiving as light—the rays which we term ultra-violet because they lie beyond the violet end of the spectrum. By means of such rays Finsen produced reaction in the skin through which certain *loci* of disease are destroyed. The fact thus demonstrated that light could be employed as a curative agent, induced physicians to study more extensively the effects of light upon the human organism. Their zeal along this line was increased when it was shown, particularly through the researches of Bernhard[1] and Rollier[2], that internal maladies likewise can be favorably influenced by sunlight in spite of the fact that their loci cannot be reached by direct radiation.

Our knowledge as to the effects of light upon living organisms was still further materially advanced by Van Tappeiner[3] and the students under him. It was observed by them that infusoria contained in certain dyestuffs perish when the latter are extremely dilute, while they frequently remain alive in much higher concentrations of the same substances. The cause of this appeared to depend upon whether light was acting upon the infusoria. This effect was termed *photo-dynamic* by von Tappeiner and was demonstrated in the case of eosin, erythrosin, and a great number of other dyes. A condition of such action appeared to be the fluorescence of such substances. It was also found that toxins, ferments, and similar substances derived from animal and vegetable organisms are destroyed by light under similar conditions; furthermore, the cells of higher organisms (red blood corpuscles, ciliated epithelium) can be seriously injured in this manner. It is possible, likewise, to make warm blooded animals including even men highly photosensitive by such means and thus injure them so greatly in a brief period of time by means of exposure to light that they

*Translated for the Scientific American Monthly from the *Biologisches Zentralblatt* (Berlin).

[1] Heliotherapie im Hochgebirge, Verlag von Emke in Stuttgart 1912.

[2] Korrespondenzblatt Schweizer Aerzte (Journal of Correspondence of Swiss Physicians) 1904, no. 12.

[3] Strahlentherapie Bd. 2 (The Art of Healing by Radiation, Vol. II).

die, exhibiting symptoms of sunstroke or heatstroke. Such substances act only in the presence of light, having no effect in the dark. This action is not due, however, as might be supposed to the formation by the light of a poisonous substance. Such media may be exposed to light for a long time without increasing their toxicity; the injury is occasioned only by the coming together of the light and the dyestuff in the organism.

I have myself obtained further evidence in regard to this question by my researches concerning the light reaction of albuminous bodies (Pflueger's Arch. f. Physiol. 1916 Bd. 164). I was induced to undertake these investigations by my studies with respect to the effect of ultra-violet rays upon the eye. The human retina is not capable of perceiving these rays directly. Under certain conditions, however, they are capable of producing severe inflammations in the eye, e. g., when one travels from the lowlands to a high mountainous region or when the eye is exposed to the intensive light of an electric lamp. Such inflammations are known respectively as snow blindness and electrical ophthalmia. They are caused however, only by the extreme outer ultra-violet rays. The inner ultra-violet rays which are also contained in the daylight found at low levels are not capable of producing such inflammation. The boundary limits of the inner and outer ultra-violet rays must be sought between λ 320 and 300 $\mu\mu$ I put the question to myself as to the effect produced upon the eye by the inner ultra-violet rays. These rays are absorbed by the lens of the eye, which fluoresces actively under their action. How does it happen that we are not able to produce any reaction in the lens with these rays? Do these rays have no stimulating action upon the lens, or, is the lens incapable of reacting to this stimulus? The latter hypothesis is correct. The lens contains neither nerves nor blood vessels. It lacks the necessary apparatus for producing a reaction. However, we find that an alteration is produced in the lens and this alteration, which gradually increases in the course of years, consists in the fact that less easily soluble albuminous bodies are created at the expense of more easily soluble albuminous bodies. In my opinion this alteration of the albuminous bodies is the effect directly produced by the light upon the albumen, which the light reaction compensates in other tissues. Since no reaction takes place in the lens to compensate this alteration, its effect is cumulative throughout the whole life and thus, in the course of time, is produced that thickening of the core of the lens which exhibits itself in the normal eye as far-sightedness between the ages of forty and fifty years. When the process continues increased opacity of the lens is occasioned, ending in senile cataract.

I have been confirmed in this view by numerous clinical observations and experiments[4]. I have proved that it is possible to produce regular alterations of conditions by means of light in solutions of the albumen of eggs, of blood serum, and of lenses. *In albuminous solutions which have been dialyzed to the point where they are free from chlorine the easily soluble albumens are transformed by light into more difficultly soluble albumens, and there are numerous substances which influence this process positively or negatively.* This can be demonstrated by precipitating such solutions, after they have been exposed to light for various periods of time, by means of the ammonium sulphate test and the sodium chloride and vinegar test. The longer the samples have been exposed to light the more quickly the alteration occurs. I tried the experiment with seven test tubes which were filled with equal quantities of dialyzed albumen and exposed in a quartz tube. These were exposed respectively to 0, 4, 8, 12, 18, 24 and 32 hours of illumination. At the end of the exposure each test tube was placed in a dark icebox. At the end of the experiment a saturated solution of ammonium sulphate was gradually added in regularly increasing amounts to the test tube. The result showed that the precipitable substance which we term globulin increases in proportion to the length of the illumination.

In another test this same albumen was employed but in this case to every 15 ccm. of albumen 5 ccm. of ¼ per cent. potash lye was added. In this case the substance precipitable by means of ammonium sulphate was diminished in proportion to the length of illumination.

The same alterations were demonstrated by means of the salt and vinegar test.

The addition of 5 ccm. of ¼ per cent. lactic acid to 15 ccm. of the same albumen solution resulted in increased precipitation under increased length of illumination to an extent obvious to the naked eye without the use of a reagent.

If fluorescing dyestuffs such as those employed by von Tappeiner in his experiments be added to the albuminous solution the alteration of the latter can be augmented. Among such substances employed by me were eosin, fluorescin, haematoporphyrin, and chlorophyl. But colorless substances are also able to influence this alteration in albuminous solutions.

What is the reason for this? The first thing which had to be determined was which light rays are the ones to produce the alteration in the dialyzed albumen. At the beginning these solutions were clear and of a pale yellow tint. Consequently they absorbed but very few of the visible rays in the blue and the violet. It was necessary, therefore to seek the specially effective rays in the invisible area of radiation. On this account I tested the albuminous solutions with respect to their capacity for the absorption of light by means of a quartz spectrograph.

The investigation showed that the albuminous solutions which begin to absorb in the blue and violet, as their yellow tint indicates, absorb the ultra-violet light with especial avidity. Hence the alterations which are produced in the solutions by intensive illumination must be attributed to the ultra-violet rays. If we add dyestuffs to the albuminous solution we obtain dyestuff albumens. The science of histology has taught us the intimate relation which exists between dyestuffs and the albuminous bodies. These dyestuff albumens must absorb more light than the ordinary albumens. To the light which they would absorb in any case must be added the rays which are complementary to their color. Hence these dyestuffs make the albumen sensitive to rays which otherwise would not act upon it. We are justified, therefore, in terming these dyestuffs sensitizers.

Let us now examine the action of the colorless substances which also influence the light reaction of the albuminous bodies. I have investigated these likewise with respect to their capacity for light absorption by means of the quartz spectrograph. Among these substances those which most strongly influence the light reaction of the albuminous bodies are those which absorb most strongly in the ultra-violet. In my forthcoming work: *Biochemische Wirkungen des Lichtes* (Biochemical Effects of Light) which will appear as Vol. 170 in *Pflueger's Archiv.* I have represented a number of such spectra. The area of absorption coincides consequently in the case of these substances with that of the albuminous solution. In this instance we cannot speak, therefore, of sensitization. It is probably best to designate these substances as photo-catalyzers.

In this work I have tried to prove that all organic substances appear to be altered by the light which they absorb. I have been able to prove that it is possible to break up organic substances into their elements and radicals by means of light. In the case of colorless substances the effective area of the light resides in the ultra-violet and in those materials which appear to be fast colored by daylight, it resides in the outer ultra-violet rays. The shorter the length of the waves the more capable they are of breaking down the structure of the molecules.

[4] Wirkungen der kurzwelligen nicht direkt sichtbaren Lichtstrahlen auf das Auge. Strahlentherapie Bd. VI, Wirkungen des Lichtes auf die lebende Zelle. Münch. medizin, Wochenschr, 1915, Nr. 19. Die Wirkungen des Lichtes auf die lebende Substanz, Pflüger's Arch. f. Physiologie, Bd. 161. Uber die Beziehungen des Lebens zum Licht. Münch. medizin Wochenschr, 1915, Nr. 39. Wirkungen des Lichtes auf dielebenden Organismen. Biochem. Zeitschr. Bd. 71. Die Lichtreaktion der Eiweisskorper. Pflüger's Arch. f. Physiologie, Bd. 164.

HOW LIGHT AFFECTS THE ALBUMENS OF PLANTS

These investigations were conducted in order to study the effect of light upon the human organism. However, light produces far more striking effects upon plants than upon men and animals. If the views above set forth are correct we must necessarily discover analogous effects in plants. The effect produced upon plants by light is most obvious in the process of assimilation. This process is conducted by the chlorophyl grain which consists of the chlorophyl and the colorless struma, the chromoplast. The first is a fluorescing dyestuff and the latter consists of albumen, which we must conceive of as being, like other albumens, sensitive to light rays of short wave length. Timiriazeff and Engelmann[5] assumed that the chlorophyl acts of the colorless struma of the chlorophyl grain as a sensitizer. Since they were not able to prove, however, that the struma itself is sensitive to light, they were contradicted by Josef and Hausmann.[6] The latter authorities held the view that we are here concerned with a photo-dynamic effect and that the chlorophyl alone acts as the conductor of energy.

"No other light-sensitive substratum is required and none in fact is present," says Hausmann. However, my own researches have shown that a second substratum is present and that we must assume it to be sensitive to light. Hence Timiriazeff and Engelmann are correct. The albumen of the grain must be regarded as sensitive to light, and it is sensitized by means of the chlorophyl, for those rays to which it is not sensitive in itself.

But the chlorophyl is not the only substance in the plant cell which is capable of influencing the action of light upon a chlorophyl grain. The cell sap penetrates the chlorophyl grain carrying to it those materials which it requires in the process of assimilation. Among these materials are included certain ones which influence the light reaction in the manner of catalyzers.

SUBSTANCES WHICH ACT AS CATALYZERS.

Thus I find that the organic acids, a large number of which I have tested, act as definite, positive catalyzers. Such catalyzers include not only substances produced by the plant itself but others which are imbibed by the roots, thus we can distinguish between endogenous and exogenous photo-catalyzers. Different substances are produced through the alteration occasioned by light according to the nature of the said substances which come together in the chlorophyl grain. These substances are more or less peculiar to the individual organism. But we must also take into account just here that the light may be composed of rays having different wave lengths and exerting different effects. In the bright colored petals of flowers different rays are effective from those which operate in the foliage. This may cause the formation in the blossoms of peculiar substances which are stored up in the reserves of the fruit and which pass over with the seeds into the new-born organism.

Hitherto the view has been held that the bright colors of flowers were intended as sign posts for insects to point the way to their food. "Bees and flowers! For the understanding mind there is a peculiar charm in the connection of these two ideas. The wide, shimmering, color-bright sea of blossoms and the world of insects which pay their visits thereto have developed side by side in mutual adaptation through the course of long periods of time towards an ever greater degree of perfection!" These words were penned as recently as 1915 by von Buttel-Reepen in No. 7 of *Naturwissen-schaften*. This view is quite erroneous in so far as it concerns the colors of flowers. Von Hess has shown that all insects including bees are color blind. It is true that Von Frisch, on the other hand, has endeavored to prove that bees may possess a limited capacity for discrimination between colors about such as that possessed by a person who is blind to red and green. But even so it is quite clear that the "wide, shimmering, color-bright sea of blossoms and the world of insects destined to visit it,'" have not developed side by side in mutual adaptation. The variegated colors of the flowers could not have been produced to serve insects who are either totally color blind or blind to red and green.

THE MEANING OF COLORS IN FLOWERS

We must seek another explanation for the significance of color in flowers. In my own opinion the colors of flowers act as sensitizers in the same way as chlorophyl in green leaves. They make a different selection among the rays of light and in accordance with such selection peculiar substances are formed which are stored up in the fruit and carried over with the seeds to the new individual. This concept of colors as sensitizers implies that they are highly important with regard to the plants' own needs.

Countless researches have proved that assimilation is occasioned mainly by those rays of the visible spectrum having a long wave length, *i.e.*, those rays to which albumen is not sensitive in itself and to which it must first be sensitized, accordingly, by means of the chlorophyl. The rays of short length appear to take less part in this process in spite of the fact that they are otherwise chemically more effective. This fact caused me to inquire how it happens that the rays of short wave length, especially the ultra-violet rays, play so little part in the assimilation process. In order to answer this question I compared plants exposed to the full light of day with others which were shielded from rays of short wave length. Cuttings of as nearly the same size as possible from the same plant were planted in pots in the same sort of garden soil. The first plant was allowed to grow freely while a large bell jar of Euphos-glass surrounded the second. This glass is yellowish green in color; it begins to absorb light in the blue and violet portions of the spectrum and absorbs the ultra-violet completely. The third plant was covered with a bell jar of ordinary colorless glass. This glass also absorbs a part of the ultra-violet from daylight. The glass bell jars had an opening at the top above which a piece of the same sort of glass was so placed that air could reach the plant but not daylight. The plants were placed side by side and watered with equal quantities of water.

The first of these plants grew freely while the second as we have said was shielded by means of Euphos-glass from all ultra-violet rays and the third was shielded by ordinary glass from a portion of the ultra-violet rays. These experiments were repeated with different plants for many years consecutively, always with the same result. The plant which grew freely exhibited nothing exceptional, while the one under the Euphos glass had grown much larger and somewhat reminded one of an etiolated plant, although it was green; the third plant raised under ordinary glass was also larger than the one grown in the open air. All three plants were grown under the same conditions except for the circulation of air which was naturally less in the case of the plants under the bell jars; naturally, likewise, the use of the bell jars involved a certain increase in temperature. This difference, however, did not exist between the plant placed under the Euphos glass and the one grown under ordinary glass and these two likewise exhibited a marked difference in height. The reason for the difference in form of the plants must be sought, therefore, in the decreased amount of light admitted. Both the Euphos glass bell jar and the one of ordinary glass prevented ultra-violet rays from reaching the plants. This was also shown by the fact that the ash which remained from the incineration of the plants was smallest in quantity in the case of the specimen raised under the Euphos glass. Thus we are obliged to con-

[5] Farbe und Assimilation (Color and Assimilation). Bot. Zeitung, 1883, 20.

[6] Die Photodynamische Wirkung des Chlorophylls und ihre Beziehung zur phoyosynthetischem Assimilation der Pflanze. (The photo-dynamic Effects of Chlorophyl and its Relation to the photosynthetic assimilation of plants) Biochem. Zeitscher. Bd. xii, S.330.

clude that the *form of plants is altered by light rays of short wave lengths and most of all by the ultra-violet rays.*

It is well known to botanists that the processes of motion in plants are affected chiefly by the rays of short wave lengths while assimilation is chiefly influenced by those of long wave lengths. I have not been able to find any explanation of the reason for this difference in action in the literature to which I have access. I believe, however, that I am capable of explaining it through physiological researches in the case of men and animals.

Rays of different wave lengths penetrate to different depths in the organism, the shorter the wave lengths the less being the depth to which the rays can penetrate the tissues. For example, if we allow the light from a quartz lamp to fall upon the cornea of the eye, we observe no alteration during the illumination; the reaction remains latent several hours before appearing. The outermost layer is destroyed whether the illumination lasts for an hour or for only five minutes. The rays which produce this effect remain absorbed in the outermost layers. The epidermis of leaves is coarser than the epithelium of the human cornea and will, therefore, absorb rays of relatively longer wave lengths from short waved light. Even after long continued illumination these rays fail to penetrate to the chlorophyl grains of plants or at any rate do so in a very slight degree; hence they can have but little influence upon assimilation; on the other hand their effects must be visible in the epidermis. We are justified in regarding the difference between leaves exposed to the sunlight and those in the shade and other phenomena of heliotropism as due to these waves. These phenomena, however, did not suffice to fully explain to me the significance of the experiment described above. I made further studies in the world of nature for a long time in the hope of discovering phenomena which might be explained by this experiment. I consulted botanists, foresters, and farmers, but I found no satisfactory explanation anywhere, and for this reason I long left my records unpublished until last year a single circumstance convinced me that I had found the correct explanation.

Some nature lover had planted an edelweiss at the foot of a monument in the Isergebirge. By reason of the transplantation from the Hochgebirge (higher mountain regions) to the Mittelbirge (middle mountain regions) this plant had assumed a form which resembled in all respects that of the plant which I had grown under the Euphos glass. The sunlight that travels from the upper regions to the mid-regions of the mountain suffers much loss of the ultra-violet rays during its passage. Thus the edelweiss was influenced in the same way as my plant, *i.e.*, the ultra-violet rays which reached it were reduced. I had produced in begonias, mignonette, peas and beans similar alterations of form to that exhibited by the edelweiss and in all cases it was similar alterations in conditions of life that occasioned these.

In order to understand these relations correctly we must know how rays of light and above all the ultra-violet rays are distributed in the atmosphere. We have no correct conception of the content of ultra-violet rays in daylight. If we break up daylight into its elements with a prism we perceive that the visibility of the light ceases at λ 400 $\mu\mu$. Beyond these limits rays exist which are distinguished by their chemical effects. When we photograph the spectrum we perceive that it extends considerably further than we can see, but even then we do not obtain a correct image since glass has considerable absorbent power, depending upon its composition and thickness, in the ultra-violet region. If we make use of a spectrograph with a quartz lens, the spectra obtained appear much longer. Under favorable circumstances the spectrum of sunlight extends as far λ 291 $\mu\mu$. The spectrum has been determined to have such an extent by means of lofty ascents in balloons. But even at ordinary levels when the conditions of the atmosphere are especially favorable, rays having waves of this length have been perceived. However, the intensity of these rays differs very greatly at different altitudes and in different seasons of the year. When the direct light of the sun penetrates the atmosphere it suffers considerable loss through refraction, reflection and bending and the shorter the wave lengths the greater the amount of such loss. Thus the diffusion in the smallest particle increases in inverse proportion to the fourth power of the wave length. If we assume that the light of λ 800 $\mu\mu$ = 1, then the violet light λ 400 $\mu\mu$ will be 16 times as much diffused and the ultra-violet of λ 320 $\mu\mu$, considerable quantities of which rays are contained in daylight, even in the lowlands, will be about forty times as much diffused. The blue color of the sky is due to the increased diffusion of the short waves of light, since these rays become turned aside or split off from direct sunlight during their passage through the atmosphere. Another phenomenon due to this is the greater blackness of the shadows in the upper regions of mountains than in the lowlands. However, by reason of this peculiar distribution of sunlight in the atmosphere a large portion of the rays is lost before the light reaches the lowlands, especially the rays of short wave lengths. However, that even at low altitudes daylight contains a goodly portion of ultra-violet rays is shown by the spectra obtained by me in Dresden at the beginning of the spring with a quartz spectrograph. Half of the spectra obtained were taken upon an ortho-chromatic plate and were produced by rays which are not perceptible to the human eye. In the summer the intensity of the ultra-violet rays increases in a much higher degree than that of the visible rays and the spectrum therefore appears to be longer. In my pictures the end of the spectrum had such a feeble intensity that it was not capable of making an impression in the chosen time of exposure.

We are not yet able, unfortunately, to measure the amount of loss which daylight suffers in its passage through our atmosphere. Our apparatus is too imperfect. As a matter of fact the best apparatus which we possess for this purpose is our own skin. When we travel from the lowlands to near the top of a mountain this apparatus reacts promptly and vigorously to the increasing stimulus of the invisible rays, only a few hours being required to produce an acute reaction. "Glacier burns" and "snow blindness" are instances of this. When we expose our invalids to sunlight at a height of 1000 m. above sea level we know that the light still contains actively healing rays, though no longer capable of producing such violent inflammations as those mentioned above, and when we seek health at resorts in the medium high areas of our mountains that the sunlight there is a far more powerful source of energy than at low levels. As we travel from the extreme limit of plant life towards sea level the intensity of the visible rays steadily diminishes, and this decrease of intensity is even more marked in the ultra-violet rays.

EFFECT ON PLANTS OF VARYING INTENSITY OF LIGHT.

My experiments have proved that the form of a plant is altered when it is protected from the action of light rays of short wave length. A similar alteration was exhibited by the edelweiss plant which was taken from the Hochgebirge and transplanted in the Isergebirge. I learn from Prof. Neger in the Tharandt that shrubs reared in the Erzgebirge Botanical Gardens and transplanted in the valley in the same sort of earth exhibited longer sprouts. I do not hesitate to generalize these phenomena.

In the higher mountain regions we have a low form of vegetation of particularly vigorous growth. This form of growth is conditioned by the large quantities of rays of short wave length which act upon the plants in such regions. As we descend towards sea-level this stimulus diminishes, and plants increase in the length of their growth in direct proportion to this diminution. It cannot be denied that other influences, such as temperature, humidity, and air currents are likewise operative, but in my opinion light is so powerful a factor as far to surpass all others in importance.

The effects of ultra-violet light on plants have been extensively studied but the amount of ultra-violet rays con-

tained in daylight is still unknown. The spectrum of sunlight extends in the most favorable circumstances up to λ 291 μμ. On Mt. Rosa, in balloon ascents extending to 8000 m., the spectrum of sunlight has been found to have almost the same extent.

At the level of the sea, also, as well as in Potsdam, Cairo, Assuan, South Africa, rays have been found to extend likewise to λ 291 μμ, given favorable conditions of the atmosphere. The spectrum of the light from the quartz lamp and from the open arc light extend much further. It is possble to perceive clearly rays in these spectra extending as far as λ 200 μμ. That the spectrum of sunlight appears shorter than spectra from terrestrial sources of light may be due to the fact that the glowing ball of the sun is surrounded by a sphere of vapor which cannot be penetrated by rays of less than λ 291 μμ.

But even if the sunlight spectrum does not differ essentially at different heights, still the intensity of the light towards the short-wave end of the spectrum diminishes very perceptibly as we go towards sea-level.

In botanical studies of the effect of ultra-violet rays on plants the quartz lamp and the open arc light have generally been used, and the fact has been overlooked that a large portion of the rays of light from these sources is not contained in daylight. Thus J. Schulze informs us of the effect of light rays of λ 280 μμ upon plant cells without knowing that such rays are not found in daylight! In the Reports of the German Botanical Society for 1917 Ursprung and Blum published the results of their researches upon the injurious effects of ultra-violet rays. Only in the first part of their experiment did they interpolate a thin sheet of glass between the plant and the quartz lamp, and in this case alone did they have light somewhat resembling daylight in the extent of the spectrum. In the following experiments they omitted the glass. Consequently rays took effect in these experiments which are entirely unconcerned in the biological processes of plants in a state of nature. The ultra-violet rays found in daylight—so far as those degrees of intensity which affect biological processes are concerned—range from λ 400 μμ to about λ 295 μμ. Within those limits their intensity steadily decreases as the distance of their passage through the atmosphere increases, but unequally, and to a greater degree at the outer, than at the inner end. This decrease of intensity must find corresponding expression in vegetation. I believe that my experiment reveals the significance of this.

The ultra-violet rays also vary much more in the course of the year than do the visible rays. This variation must likewise be expressed in vegetation and this fact must be noted. Such biological processes occurring in nature can not be explained by researches in which light of less than λ 300 μμ was employed.

Tar Disposal in a Producer-Gas Plant*

A Method of Vaporising Tar That Has Proved Successful

IN the manufacture of producer gas there is formed a large amount of coal tar, which passes over with the hot gas in the form of a vapor and, when cooled, condenses into a tar fog consisting of finely divided particles that remain in suspension. This tar must be removed from the gas to avoid clogging of gas burners, sticking of engine valves and obstructing of gas-pipe lines. Along this line the Ford Motor Company is doing the unusual in that the tar is returned to the producer, discharged over the fire and successfully vaporized. The accompanying diagram of piping and much of the descriptive matter of this article apply particularly to the gas-producer installation of the plant at Ford City, Ontario, but are also more or less typical of the Highland Park and Dearborn plants.

Referring to the diagram, the path of the gas is from the producer through the downcomer and primary condenser to the low-pressure gas header. The gas from the several producers comes together at this point. The several gas exhausters receive their supply from this header and discharge through spun-glass tar extractors in parallel, thence through secondary or cooling condensers to the gas-distribution main or header. Considerable tar is removed from the gas by water sprays in the primary condensers and practically all the remaining tar is removed by the spun-glass tar extractors. A trace is removed by aftercooling water sprays in the secondary condensers.

At present the cooling water from the primary and secondary condensers is mixed and sent to the tar-settling tank where most of the tar settles to the bottom. The water from the secondary condensers in a short time will be diverted directly to the sewer, thereby increasing the efficiency of tar separation from the primary water. The low-pressure gas header acts as a tar receiver. The tar flows by gravity, assisted by the head of water in the settling tank and the gas-exhauster suction, from the tar-settling tank to the low-pressure gas header. The tar from the spun-glass extractors likewise flows back by gravity to this same gas header, assisted by the difference in gas pressure on the two sides of the exhausters.

Previous to 1916 the tar was a waste product of the gas-producer plant and was hard to dispose of on account of its pitchy nature and the impurities it contained. It was got rid of by being sprayed into the boiler furnace. The small saving in fuel in no way repaid for the nuisance of the frequent plugging up of the tar lines, clouds of black smoke from the stacks and the mess in the plant.

It seemed desirable to dispose of this tar by gasifying it in the producer. All efforts along this line previous to August, 1916, had been so uniformly unsuccessful that it was generally admitted at that time that the idea was not practicable. However, on the suggestion of H. F. Smith, who had previously done considerable work on the problem, another attempt was made at the Highland Park plant, which established the fact that the tar could be gasified and would increase the heat value of the gas. Profiting by this experimental work, when the Ford City plant was put into operation the producers were piped up to dispose of all tar. The development of details has been rapid. The several plants differ materially in respect to details of construction and operation, yet the essential features are the same and each accomplishes the same general results.

Temperatures are the most important factors in the handling of the tar. Good practice requires that the gas leave the producer at a temperature of approximately 1,000 deg. F. In the primary condenser the gas should be cooled down to about 125 deg., this being about the lowest temperature at which the tar remains liquid. If cooled too much, the tar particles will stick and build up on the spun-glass extractors. The temperature of the gas leaving the secondary condenser should be as low as the water supply available will permit in order to eliminate the last trace of tar and moisture.

The tar that is collected in the low-pressure gas header in the basement may be pumped to the tar sprays in each section of the producer by a small rotary pump. The speed is regulated so as to return the tar at a slightly higher rate than it is received from the tar extractors and tar-settling tank. The pump may then be shut down, if desired, at times of light load.

*From *Power*.

As an auxiliary to the pump a small pressure tank is installed below the low-pressure gas heater. The tar flows by gravity into this tank, which has an overflow so that the small amount of water that may accumulate can be drawn off. When the tank is full of tar, the connections are closed off and steam is admitted at a pressure of from 40 to 50 pounds per square inch. The tar is discharged through a pipe from the bottom of the pressure tank and delivered to the producer sprayer *A* through the same pipe line *B* into which the tar pump discharges.

The advantage of the pressure tank method of handling tar is that it has no moving parts and the pipe line and all connections are blown clean of the tar by the steam after the tank has been emptied. On the other hand, the tar pump has the advantage of giving a more constant feed of tar to the sprays.

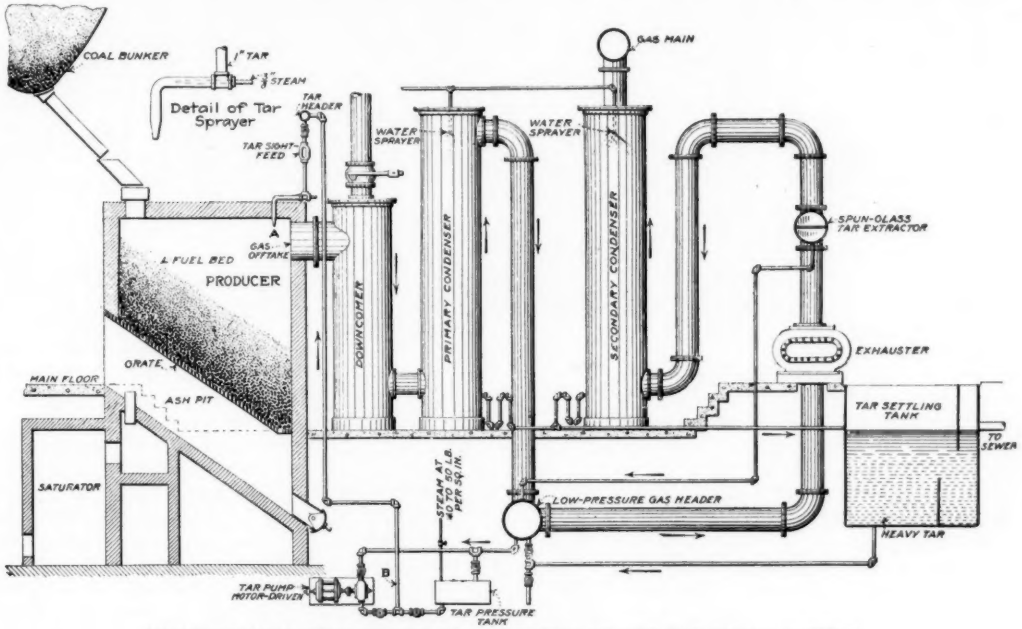
In the Ford City plant a 96-gallon pressure tank is used in preference to the tar pump. The objection to an intermittent supply of tar to the fire has recently been overcome by first delivering the tar to an overhead storage heater running the full length of the battery of producers. The tar sprays are supplied continuously from this header. With continuous operation and constant maintenance of temperature throughout, it has been found possible to keep the tar so fluid that it is being fed like oil through sight feeds to each section of each producer.

The sprayer by means of which the tar is atomized and distributed over the fuel bed is made by placing a ⅜-inch steam pipe inside a 1-inch tar pipe. The ends of the steam pipe and tar pipe are reduced in area so as to increase the velocities of the steam and tar to aid in the atomizing. The ends of the sprayer are approximately flush with the bottom face of the top lining of the producer.

Vaporizing the tar increases the heat value of the gas about 10 to 15 B.t.u. per cubic foot. The difference shows up in the analysis of the gas in an increase of from 1 to 2 per cent of methane, accompanied by a slight reduction in the percentage of hydrogen.

The chief trouble encountered when first returning the tar to the producer fire was the formation of soot when the tar was sprayed upon a fire that had holes in it. This soot, if allowed to accumulate, would plug up the spun-glass screens in the tar extractors in a very few minutes. It is necessary to keep the fuel bed in good shape and free from holes when spraying tar. The tar should be evaporated over the full area of the fuel bed and not burned as would be the case were there a hole in the fire. Five sprays are employed to insure even distribution over the fire. With a smaller number of sprays of tar the fuel bed under each spray became saturated with tar.

In the past considerable trouble has been experienced from solidifying of the tar in the pipes when the pump was shut down. This may come about due to cooling or to "baking." If the tar is allowed to cool in a pipe line, it is difficult to get it moving again. Provision is therefore made in every case for blowing tar from the pipe lines by the use of a ¼- or ⅜-inch low-pressure steam line run either inside the tar pipe or, preferably, on the outside and inclosed in the same pipe covering. The pressure on these steam lines should be five pounds or less. Tar should not be allowed to remain quiescent for any considerable length of time in a pipe even though heated, since the lighter oils will distill off and the residue harden or bake in the pipe, making a condition as bad as or worse than when it solidifies owing to cooling. The new sight-feed tar system requires that the temperature of the tar be maintained at about 160 deg. F., and for this purpose a low-pressure steam pipe is run inside the tar header over the producers.



DIAGRAMMATIC VIEW OF THE ARRANGEMENT OF THE TAR-PIPING SYSTEM

TUNGSTEN IN BURMA.

TUNGSTEN and tin occur in Burma and mining on a small scale, particularly for tin, is an ancient industry. Military need for tungsten has caused general interest in the world's resources of the metal and has caused the Geological Survey of India to publish a summary, prepared by Messrs. Brown and Heron, on the deposits in Burma.

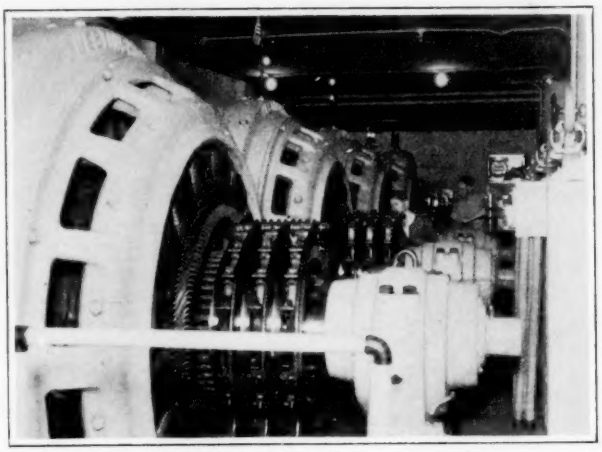
Active prospecting has been carried on in recent years and a considerable amount of tungsten has been produced. Usually wolfram and casiterite occur together, but sometimes they occur separately. The ores are found in lodes and are always associated with an intrusive granite that forms the core of the great mountain system which stretches into Western Siam and the Malay States. The authors believe that conditions are favorable for the discovery of further deposits in the vast areas of Burma which are as yet imperfectly known.

A Wireless Storm Detector for the Central Station

Anticipating Thunderstorms and Atmospheric Darkness at the Power Plant

By Herbert T. Wade

IT is not generally realized how intimate is the connection between meteorology and many fields of applied science and industry, but a striking instance is found in the public service company that supplies light and heat. In connection with schemes of daylight saving, the shortening of the time during which artificial illumination is required and the consequent saving of fuel has figured prominently, and the superintendent of the electric lighting company is a close observer of the changing time of sunrise, as his load will vary accordingly. This, however, can be anticipated in advance and the experience of previous years availed of, but when a sudden thunderstorm or other atmospheric disturbance comes, where the sky is darkened in the middle of the day without warning, the matter is an emergency which requires hurried and vigorous measures in the power house. When a city is covered with virtual darkness in the middle of the day, it means that resort must be had to artificial illumination, and immediately electric lights in great numbers are switched on, thus producing a sudden and abnormal load on the system, say at two o'clock in the afternoon, when under ordinary circumstances it would be at least six or seven o'clock, or even later, before the peak would be reached. A storm producing such sudden darkness may come up quickly, and apparently without warning, so that it would seem impossible to provide at short notice sufficient current or steam for the engines or turbines driving the generators. In the larger cities the usual practice is to have a central station of considerable capacity and to distribute alternating current to various substations conveniently located, at which it is transformed to whatever voltage is employed for lighting or power. At these substations the transformation of current from the central station is effected by rotary converters. Of course when an increased load comes upon the substation, due to the turning on of a number of lamps, it is a simple matter to start in operation additional rotary converters and thus secure increased current. This, however, simply increases the load on the central station, where adequate steam must be provided in the boilers to operate the turbo-generators.



ROTARY CONVERTERS AT SUBSTATION

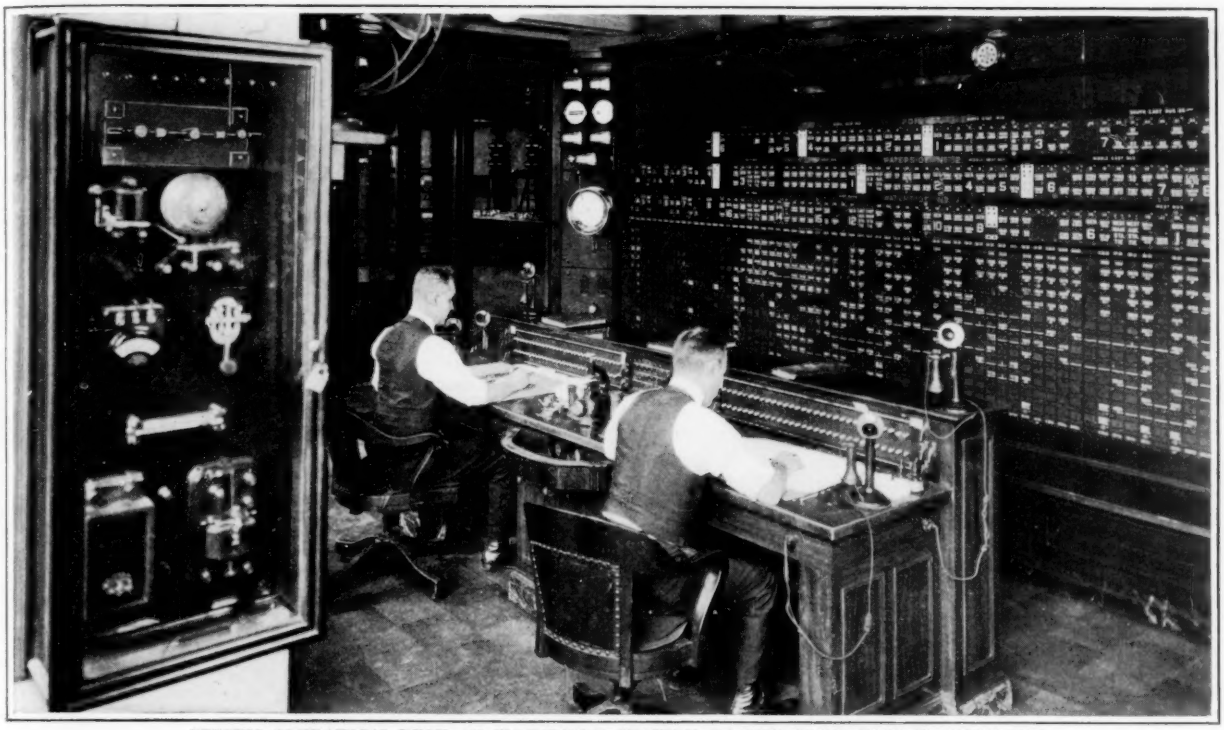
These convert alternating currents to direct for distribution

Accordingly the electric light company seeks to know as far in advance as possible the coming of a thunderstorm, and at the Waterside Station of the N. Y. Edison Company there is maintained a wireless signal at the central control office, where a threatened change in atmospheric conditions presaging a storm is announced to the system operator, some time before the arrival of the storm, by the ringing of a bell.

It is apparent that an electric light central station is required to function so as to provide adequate current for lighting, whatever the condition of weather or sudden calls that may be made upon the system. Naturally it is unable to maintain a reserve in any central reservoir, as in the case of gas or water, but the current must be generated and distributed immediately as required. The management of a central station, therefore, is forced to study the ordinary conditions of its daily operation and load very carefully, and accurate and detailed records are made and studied so as to know at what times of day the natural increase or decline in consumption will take place under normal circumstances. In addition a central station is forced to provide for sudden and unusual drafts on the current, some of which may be anticipated, and some of which may come without warning. For example, in the case of a general illumination, it is quite possible to arrange in advance, but where a sudden thunderstorm or darkening of the atmosphere occurs, and everybody immediately switches on their electric light, it is not always possible to foresee this sudden demand in time to provide the required capacity. It is true that each substation of a system may maintain a storage battery installation that will carry a certain portion of the load for a more or less brief interval of time and be available while other parts of the system are out of commission until repairs are rapidly made, or until sufficient generating capacity is added. For example, in New York the direct current substations in Manhat-

STARTING ROTARY CONVERTER

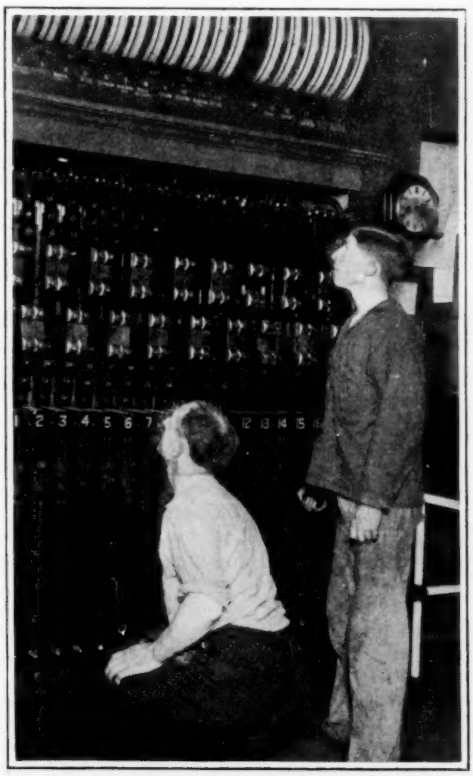
Starting box used to start and turn over a rotary converter



SYSTEM OPERATOR'S DESK AT WATERSIDE STATION OF NEW YORK EDISON COMPANY
Storm detector is in case at left and pilot operating board in background

tan of the New York Edison Company have a battery capacity of 50,000 kilowatts for one hour, and every substation has its battery. In the main, however, dependence must be placed upon the boilers and generators at the central station, as the approved system of electric lightning now calls for a high capacity central station with large steam turbine-driven units which generate alternating current and distribute it to various substations located throughout the city, where it is transformed by rotary converters to direct current and distributed within the immediate territory served by the substation. The New York Edison Company represents a typical installation, yet at the same time it is in many respects so far in advance of the best average practice as to be unique rather than characteristic of a large capacity station.

At its Waterside Station, located on the East River, convenient for unloading coal, a number of steam turbine-driven generators are maintained which produce alternating current, 25 cycles at 6,600 volts, which is then distributed throughout Manhattan Island to various substations of the Company and to such independent substations as the high pressure fire pumping plants of New York City, contractors engaged in subway construction, street railway companies, etc. The efficiency of the plant demands that the boilers should be run at their most economical rating, and the amount of steam produced is considered with regard to the daily and ordinary fluctuation of load. Where the boilers are run at an economical rating, 30 per cent above this amount readily can be taken care of, and in addition a certain number of boilers are carried banked, which can be brought up to steam pressure with 150 per cent load in about five minutes. To bring up a fresh boiler that has been inactive, two or three hours are required. It will be seen, therefore, that the boilers are the main consideration in case of sudden increase in load, as the turbine-driven generators can be put on in a couple of minutes, provided there is steam enough to take care of them.

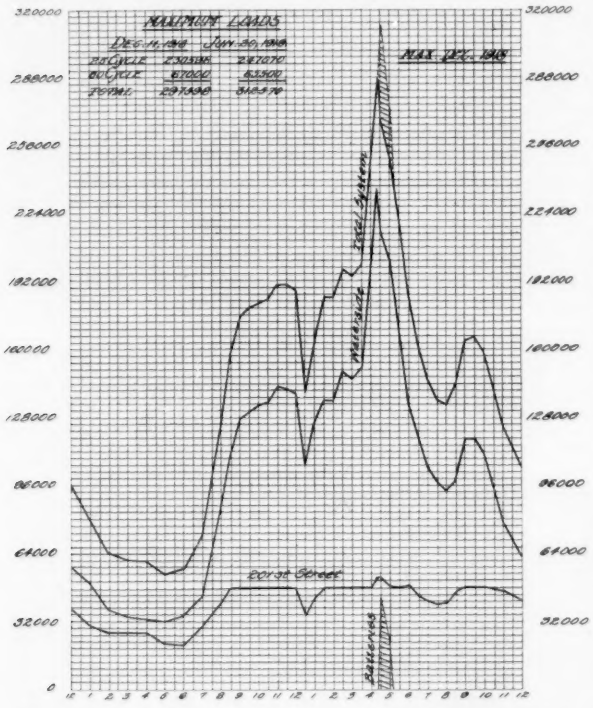


DIRECT CURRENT SWITCHBOARD AT SUBSTATION

In a system like that of the New York Edison Company, the various substations are connected by feeder cables with the main generating station at Waterside, and these substations add their various rotary converters, as increased current is demanded in their immediate district. These drafts must be met at the main central station at Waterside, and in case of a sudden storm darkening the entire city, the amount of extra current required may run up from 50 per cent to 75 per cent. As will be seen from the diagram on page 20 on June 20, 1919, between 3:30 and 4:20 in the afternoon, current consumption increased 120,000 kilowatts, where-

as on a normal day it would have remained stationary or possibly declined. Supplied from the one central station at Waterside there are 27 substations devoted to direct current illumination in Manhattan, and a number of substations belonging to large consumers such as the city, traction companies or contractors. In addition, in the Bronx and outlying districts alternating current at 60 cycles is supplied also from Waterside, but transformed to 110 volts.

It will be apparent, therefore, that those in control of the Waterside central station, even with its large capacity, require the earliest possible warning of an approaching storm or atmospheric conditions that will lead to darkening the atmosphere and the demand for more current. It was with this in mind that the electric storm detector was devised with its antennae or aerial wires mounted on the roof of the Waterside Station and its signal and indicating mechanism in the office



LOAD DIAGRAM ON JUNE 20, 1918—SUDDEN RISE DUE TO THUNDERSTORM

of the system operator, who is responsible for the entire operation of the generating and distribution system of the plant.

The system operator sits in an office where he has under his observation an operating pilot board with interconnecting control signals and indicators that show the entire functioning of the various stations and elements of the system, and he is responsible for the providing of additional and adequate capacity, so that both the ordinary and sudden loads may be taken care of. He and his assistant sit at a desk, as shown in the illustration, and in front of them is a pilot board, where is indicated each generator in the central station and its connection with the bus bars and the distribution of the feeder cables to the various substations. Each of these feeder cables has an approximate capacity of 3,000 kilowatts, and in some cases 4,000, and on the board each of these leading to the substations is indicated. On the lower part of the board the indications represent the various substations and their feeders, and the lights show which of these are in use. This board, which is unique in being the only one of its kind, is absolutely automatic, and shows the condition of the generating units and capacity and the distribution to the substations for the entire system. A red light indicates just which feeders are in use, and any interruption of service is shown by a green light. These bullseye telephone lamps are part of a circuit that extends to the oil switches of the main feeder circuits and indicate automatically and instantaneously whether these circuits are open or closed. The various substations are connected by tie feeders, so that a complete interdependence of the various elements of the system is assured and failures of certain lines can be taken care of.

In brief, the system operator, who is connected by direct telephone circuits with each of the substations and pneumatic tubes and signals with the boilers and generator rooms, is able absolutely to control the operation of the system. Indeed, in case of an emergency he has at his command a regular fire alarm transmission system, extending to each substation over which he may send out instantaneously and simultaneously various code signals. In the boiler room there is a signal like the carriage calling device at a theater, and when a new boiler is ordered into service, the appropriate punched card is inserted in the transmitting machine and the signal is made. The responsibility of this office can be appreciated, as the entire economy of the station and system are here controlled involving the provision of an adequate supply of current to satisfy the various consumers. If an over-capacity of boilers is maintained, it is done at the expense of fuel, while on the other hand, if the system is caught at some time of sudden darkness with inadequate capacity, the trouble is no less serious. It will be apparent, therefore, what part meteorological conditions play in the ordinary routine and maintenance of the station and why the system operator needs the earliest possible warning to increase his output or prepare for sudden demands.

In the summertime a heavy thunderstorm may bring practical darkness to the city and produce a condition so different from the ordinary routine seriously to threaten the efficiency of the service. In the winter such matters do not figure so largely, as the ordinary load is so much greater that the sudden increase due to the darkening of the atmosphere does not tax the system so seriously. In summer, however, storms are likely to come up suddenly and the atmosphere considerably darkened, so that electric light is switched on generally, and the load on the lighting system may increase 50 per cent or more. The most striking instance of this sudden increase of load is shown in the accompanying curve for June 20, 1919, which shows actual output in excess of the previous maximum capacity of the entire system namely, that of December 11, 1918. On June 20th the maximum load at 4:20 P. M. amounted to 312,570 kilowatts, while on December 11, 1918, the previous maximum, it was 297,598 kilowatts.

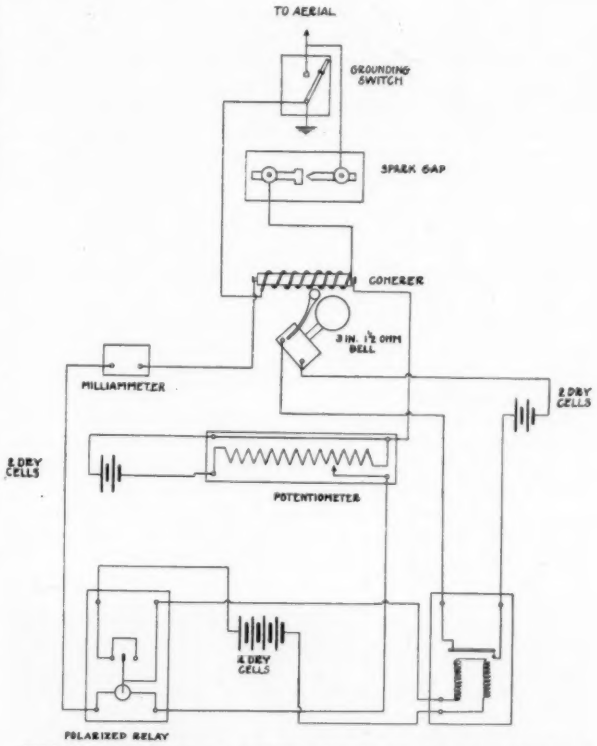
Such conditions as these naturally demand every measure to give warnings of storms as far as possible in advance, and it has been found that weather bureau reports are not always accurate for this purpose, nor do they indicate storms which actually strike the territory as distinct from those which pass around it. Accordingly a special form of storm detector was devised some years ago and has been in successful use at Waterside Station. Inasmuch as summer storms are accompanied by electrical disturbances of the ether, which are indicated by means of a special form of wave detector, it was decided to install such an instrument at the Waterside Station, as these electrical disturbances cover a field further distant than the clouds themselves are visible. Accordingly a system of antennae is used to intercept such distant radiations and to indicate by suitable form of detector and signal not only the presence but the relative proximity of the storm. As stated, this is confined largely to summer storms, as the winter storms are usually snowstorms and of a weak electrical nature, while at the same time the load carried by the station in winter is more uniform, and no storm ever comes up to the peak of the load ordinarily carried between 5 and 5:30 in the afternoon. In the antennae, mounted on the roof of the station, the presence of electrical disturbances in the atmosphere gives rise to oscillating currents which travel

through the aerial to the ground through the spark gap coherer and condenser. The general arrangement of the apparatus is indicated in the accompanying diagram, and is shown on the left of the photograph of the system operator's office. At the top of the diagram will be seen the short circuit switch which grounds the apparatus when it is closed after the bell rings continuously. Inasmuch as by that time the storm has already arrived, it is not necessary to use the apparatus, and it is thus protected from the heavy surges. Next the aerial circuit is connected through a spark gap supplied with spherical terminals about 1/64 of an inch apart and a coherer of the type formerly used as a receiving device in wireless telegraphy. The function of the spark gap is to prevent those electrical surges induced in the antennae by the radiations emanating from wireless telegraph stations, which are very weak as compared to the electrical disturbances in the atmosphere, from flowing through the remainder of the apparatus and thus causing a false alarm. The coherer is also in circuit with a milliameter, a polarized relay, a standard relay, and a single stroke bell whose clapper not only strikes the bell itself but also the glass tube of the coherer, causing the particles in the latter to decohere after each impulse. The action of the apparatus is sufficiently apparent from the diagram, and it involves no applances that are special or unfamiliar. It is completely automatic in its operation. At a time varying from 2 to 7 hours, depending upon whether the path of the storm is direct or roundabout, the bell may begin to ring at intervals of from five to fifteen minutes, giving a warning of some distant atmospheric disturbance, indicating a storm possibly one hundred miles away. This is regarded merely as a preliminary warning, for as the storm approaches, the bell will ring more frequently. When about two hours away, the bell will ring about once every half minute or minute; and when this occurs, the reserve boilers are ordered into service and the auxiliaries of extra generating units are started and the generating units themselves may be run at low speed. This is entirely preliminary and by way of preparation as the storm may be approaching yet pass by at a greater or less distance. The bell rings continuously about one-half or one hour before the storm reaches the city, and even at this time the sky may be unclouded to the eye, even to an experienced storm observer. However, everything now is in readiness to meet the demand, and with the bell ringing continuously the short circuit or ground switch is then opened so as to protect the apparatus. The storm warning involves entirely a measure of preparedness and attention to the immediate boiler and generating capacity available and the ordering of banked boilers into full service and other boilers as may be required, or, in case of an extreme emergency, the batteries.

As soon as the storm strikes the city, the switching on of electric lights means extra drafts on the current supplied from the substations. Those in charge of these plants notice that the amount of energy consumed is increasing, and they immediately add extra rotary converters to take on the load. These rotary converters take the alternating current at 6,600 volts, 25 cycles, and transform it into direct current at 120 volts, except in some cases in the upper parts of the city and suburbs where customers are supplied with alternating current at 110 volts.

The work at the substation, which is shown in several of the accompanying photographs, is of course not as involved as at the main central station where the energy is generated. Nevertheless rotary converters must be held in readiness for instant service. When it is found that more capacity is required, extra rotary converting units are started up, the operation being as shown in the accompanying figures. The amount of current is increased as required, and the system operator at the Waterside Station notes the load carried by the feeders running from the generating station to the substation and keeps up the capacity. Here those in charge note the consumption of the direct current supplied by their rotary converters, and the photograph shows the direct current switchboard where the sudden overdrafts are first apparent. Here, as stated, more rotary converters are added as needed, this of course making a corresponding load on the feeders and on the main generating system. The feeders carrying the direct current from the substation to the consumers are shown in the accompanying illustration:

Where large currents at high voltage are used, an oil switch is required. In contrast with the heavy oil switches, small hand switches shown on the lighting panel of a substation are of interest.



WIRING DIAGRAM OF STORM DETECTOR AT WATERSIDE STATION

The substation is at all times in complete communication with the system operator by telephone and indicator, and while its responsiblities are far less than the main generating station, yet its needs and the needs of the consumers must be taken care of immediately.

It should be borne in mind, however, that a system so large as that of tie New York Edison Company can be and is under a single control, and the ingenious device described above is but one element in this vast distribution of light and power, although it helps to take care of the very important item of sudden overloads due to atmospheric conditions.

THE ELECTRICAL INDUSTRY IN BELGIUM

THE electrical industry in Belgium is gradually resuming its activity. The main difficulty, however, is that it is practically dependent on foreign countries for the supply of the material required. In the large towns, Brussels in particular, a start has been made to lay the supply cables that were held up during the war. The networks that were removed by the Germans are also being replaced. A significant indication of the activity which is anticipated in the industry is the increasing formation of new companies and groups dealing with contract work and the purchase and sale of material. Many existing firms are considerably increasing their capital.—From *The Technical Review.*

Submersible Sea Salvage Pumps*

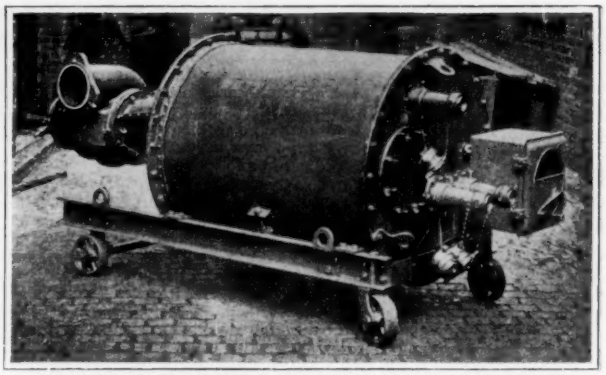
A Portable Apparatus for Pumping out Flooded Compartments

DURING the war, as we know, an enormous amount of time and attention was devoted by inventors, scientists, naval architects, and shipbuilders, to the possibility of keeping a ship afloat after she had been badly holed by mine or torpedo. It is quite obvious that if a compartment is so severely damaged as to allow of the proverbial coach and horses being driven through it, no pumping apparatus that human ingenuity can devise will keep the water out. It is, however, quite within the range of possibility that the compartments adjacent to those damaged may be kept free from water, even if the bulk-heads, through strain, are leaking freely, provided apparatus is ready for instant use in such an emergency. That apparatus must be both reliable and powerful and easy to handle. It is now a well-known fact that the large steamship companies suffered very heavily from enemy action, and it is known that on several occasions, when a ship was mined or torpedoed near shore, she could have been successfully beached and subsequently salved had it been possible to keep the water out of only slightly damaged compartments for a few hours.

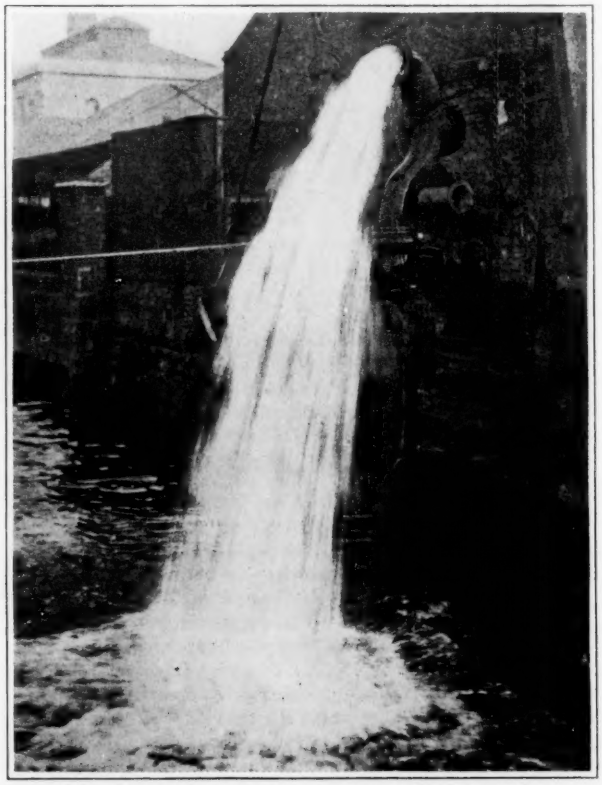
The portable electric pumping apparatus here illustrated has been specially designed and constructed to meet such requirements as those brought about by the conditions we have just indicated.

At the present time, there is probably not a ship at sea; at any rate, not a ship of any size, which is not equipped with an electric power installation for lighting purposes, and some have a special power plant on the upper deck, entirely separate from the ship's ordinary lighting set in the engine-room, and intended to be used in an emergency. This special power plant is, we believe, rendered compulsory by the Board of Trade to meet the regulations laid down by the International Convention for the Safety of Life at Sea, drawn up prior to the war, and which, it is hoped, although many times postponed on account of the war, will soon become effective on all the high seas of the world. Should it so happen, therefore, that the vessel be damaged in the vicinity of the engine-room and the dynamos put out of action, the emergency plant would come instantly into operation, and provide current for lighting, for operating the ship's derricks, and for driving such a portable pumping apparatus as that which we are now describing.

*From the *Shipping World*.



ELECTRICALLY-DRIVEN SUBMERSIBLE SALVAGE PUMP



THE SUBMERSIBLE PUMP WORKING UNDER WATER DURING A 48 HOURS' DURATION TEST

The electric submersible pump consists of a centrifugal pump of the standard sea salvage type, coupled direct to an electric motor carried in an hermetically sealed steel cylinder. A special feature of the apparatus is an intercepting chamber arranged between the motor and pumps, forming subject matter for which a patent has been applied, and which is designed to prevent any posibility of water from the pump chambers finding access to the electric motor. That the success of this device is assured is demonstrated by the fact that a continuous working test of forty-eight hours' duration, with the pump completely submerged has failed to show the slightest leakage of water into the motor cylinder. Moreover, for well proved reasons a ship's power plant is almost without exception designed to a low voltage continuous current, and the submersible pump can be successfully operated direct from an ordinary ship's lighting set. This, it will be readily appreciated, is an extremely important feature.

The submersible pump illustrated, has an 8-inch diameter suction, and is capable of giving an output of 1,100 gallons per minute against a head of 35 feet. An overall efficiency of 75 per cent has been demonstrated by actual test, which is extremely high for this class of pump.

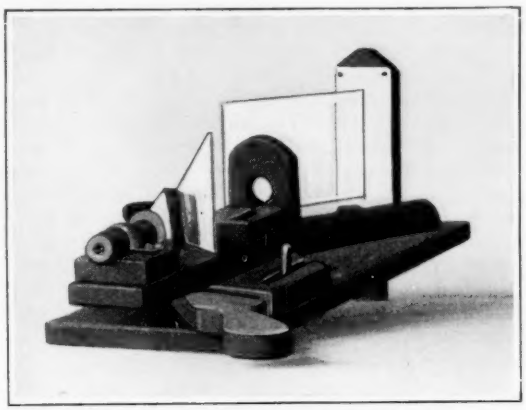
These pumps can be operated when slung vertically or when fixed in a horizontal position, either on or off the trolley with which each is supplied. Although they will run successfully when totally submerged, they will run equally well when fixed above the water level. It should be recognized that in most instances where access has to be obtained to a flooded compartment, it is, generally speaking, more convenient to use a length of flexible suction piping of such a diameter that it can be inserted through a small orifice—such as a porthole, for instance—than to lower the complete pump into the water; and it will, we think, be found in actual salvage practice that the necessity of submerging the pump would arise on comparatively rare occasions. There are, however, cases in which a rapid rise might flood the pump, and hence the necessity for constructing it in such a manner as to

allow of its continuous operation under the most adverse circumstances. The power cable connections are, of course, watertight, and arranged with a swivelling nut, much in the same manner as a standard screwed hose coupling. Each pump is supplied with a hand-operated air pump fixed to the carriage, for charging the pump suction when operated from about the water level.

REFRACTOMETER FOR POLISHED PLATE GLASS.

BY K. A. RICE, M. E.

A REFRACTOMETER which determines the index of refraction of polished plates of glass, accurate to the third decimal place may be made as follows. A simple telescope consisting of two lenses of three or four diopters focus each, and having a card with a narrow slit (.02" wide) at their common focus is mounted upon a slide which permits the



DETERMINING THE INDEX OF REFRACTION OF A PLATE OF GLASS

telescope to be shifted at right angles to its line of collomation. The slit in the card must be vertical. The telescope is mounted on a base board between two cleats which run crosswise to the length of the board, and one of which is provided with a clamp for holding the telescope rigidly in any desired position. At the end of the board opposite to that occupied by the telescope is placed a second card with a vertical line drawn upon its inner face. Between this card and the telescope a cleat is secured to the base at an angle of 30° with the center line of the base, against which the plate to be measured is placed. A simple clamping device holds the glass in position snugly against this cleat. Means are provided for accurately measuring the position of the telescope with respect to a fixed point on the base, two steel rods being used in this case, one on the telescope slide and one on the slide guide, the distance between them being measured by means of ordinary micrometer calipers.

In operation, several measurements are made of the thickness of the glass by means of the micrometers, and the average of these noted. Ten readings are recommended. Then, sighting through the telescope, with no glass in the path, the telescope is shifted until the farther black line is located in the center of the slit (the line also being in focus), and clamped in this position. Then the distance between the outside edges of the steel rods is measured and noted. Now the plate is interposed, being clamped against the 30° cleat, and the telescope shifted until the line again appears in the center of the slit, clamped, and measurement between steel rods again taken. It is well to take ten readings for this value also, taking five with the glass in different positions with the end in one direction, and five in different positions with the glass turned end for end, in order that any defects in the glass, such as local imperfections or to a wedge shape between the two surfaces, be compensated. The average of these readings is found, and the zero reading (reading without the glass) is subtracted from this, giving the value "*d*". This number is divided by the thickness as found above, and with this last result, the index of refraction may be read directly from the curve.

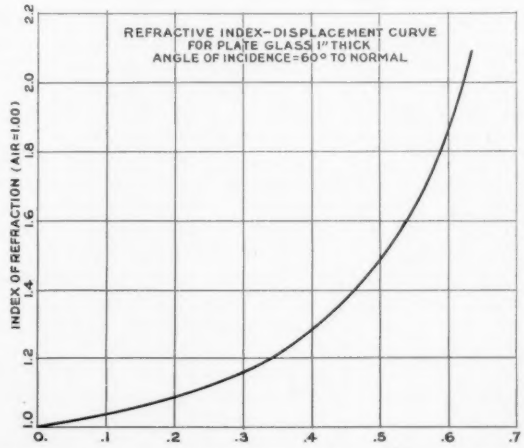
The theory upon which this apparatus is based, is that when a beam of light passes through a plate of glass with parallel surfaces, the beam is emitted in a line parallel to that of the original beam, but displaced from it by a distance which depends on the index of refraction, the thickness and the angle at which the glass is interposed. This latter must obviously be other than 90° or 180° to the normal. With this in mind, the following formula was developed for the index of refraction, in which Θ is the index, t is the thickness, and d is the displacement, the angle employed being 30°, or 60° to the normal:

$$\Theta = \frac{\sin 60^\circ \sqrt{t^2 - 2td \sin 60^\circ + d^2}}{t \sin 60^\circ - d}$$

From this equation it is evident that, the index of refraction and the angle of incidence being constants, the displacement of the refracted beam is directly proportional to the thickness of the glass. Therefore the curve was calculated for an angle of 30° to the glass, or 60° to the normal, with index values ranging from 1.0 to 2.0, and with the thickness 1 inch. When the curve is used, the value for *d* obtained from the instrument must be divided by the thickness of the glass, as explained above, in order to reduce it to an equivalent plate of that standard thickness. The computed points on which the curve is based are as follows:

Index	Displacement
1.0364	.08
1.0612	.16
1.1061	.24
1.1743	.32
1.2702	.40
1.4270	.48
1.6588	.56
2.1026	.64

It is evident that the last figure in the indices as above computed cannot be plotted on this curve, so it was eliminated by reducing the index values to three significant figures beyond the decimal point. A sample computation of refractive index is submitted as a guide.



Ten readings for thickness ran from .0826 to .0831, with .083 as the average. The glass readings varied from .392 to .394; the average was .393; and .347 was the zero reading. Then d=.393—.347=.046 inches. This value for a thickness of .083 reduces to .046÷.083 for a thickness of one inch, so that the corrected d=.554; then from the curve, 1.635 is the index of refraction corresponding to this value of d.

Automatic Regulation of Humidity in Factories

Conditioning Apparatus Developed at the U. S. Forest Products Laboratory at Madison, Wis.

IT has long been known that green lumber warps out of shape and that the grain curls excessively when planed or carved, so that for use in furniture and cabinet work lumber must be dry. From one to two-thirds of the weight of a tree, when it is cut down, may be due entirely to the water it contains. If the wood is left exposed to the atmosphere, the moisture is slowly given up, until equilibrium with the atmospheric conditions is reached. In some climates this occurs when the moisture is 27 per cent of the weight of air dried wood; in others not until the moisture content becomes 4 or 5 per cent. Air-drying is usually a slow process and is accompanied by serious checking and warping. The artificial drying of wood without injurious results can be accomplished only by a careful drying schedule. It is possible, however, to cut the material up and dry it in kilns to any desired content without the materials becoming checked or warped.

Wood contains water in two forms, either as free water, like honey in the comb, or as hygroscopic moisture, actually permeating the cell-wall tissue. No change in shape takes place while the free water is being removed, but as soon as hygroscopic moisture is removed, the wood shrinks. This shrinkage is different in degree for every species of wood, and even within a species it is different in each of the three directions in a tree—radial, from the heart toward the sap; tangential, along the circumference, or the annual ring; and longitudinal, from top to bottom in the tree. With any change in hygroscopic moisture, there is an immediate shrinking or swelling of the wood in each of these three directions, and by a different amount in each direction.

Changes in moisture content, then, are important because they cause wood to shrink or swell. If the moisture content of a piece of furniture changes after it is made up, the dimensions of the different pieces will be altered, and, since the alteration may not be the same for all parts of a piece, warping is likely to take place. If the moisture content of the material used in making a single piece of furniture is not uniform at manufacture, it will become uniform after manufacture, and, while some parts may shrink, others may swell, and severe warping and checking or even splitting may occur. This is particularly true in the manufacture of airplane propellers and fine cabinet work, where pieces have been made to fit exactly. In such articles severe stresses are set up with small moisture changes. In airplane propellers these stresses frequently cause joints to open, blades to warp, and the propeller itself to go out of balance.

The moisture content of wood has been found to depend upon the temperature and humidity of the atmosphere in which it is placed. By controlling the atmospheric conditions, it is possible to bring and hold the moisture content of wood to any desired value.

Along with other problems relating to the moisture changes of wood, the problems of the proper moisture content for specific war purposes became acute enough to require particular investigation. With the establishing of an airplane propeller plant at the U. S. Forest Products Laboratory at Madison, Wisconsin, the necessary rooms were provided in which the atmosphere could be controlled and its temperature and humidity held at any desired values, irrespective of outside atmospheric conditions.

Conditioning devices may be divided into three classes—non-controlled, semi-controlled, and absolutely controlled. The non-controlled type includes such methods as running water in troughs along the side of the room, or passing the air over wet wicks. Other examples that may be given are the sprinkling of water or wet sawdust on floors, or the spraying of water directly into the air. The semi-controlled type includes most of the commercial forms of humidifiers. These are capable of increasing the humidity up to the value for which they are set, at which point the apparatus stops operating. The controlling feature for these types is usually some cellulose material, such as wood or fiber. This type of apparatus is not capable of reducing the humidity. The absolutely controlled type is capable of reducing the humidity, as well as increasing it.

Relative humidity may be decreased in several ways. The air may be heated without addition of moisture; this is what ordinarily happens in factories during cold seasons. Cold air is drawn in from the outside, is heated, and circulated throughout the shops, giving relative humidities of 10 to 20 per cent; while in the warm seasons, the relative humidity would be as high inside the shop as outside, usually from 45 to 00 per cent. Low relative humidities could be secured in summer as well as in winter by heating, but the necessary temperature, probably 120° F. or more, would be excessive. Refrigeration could also be used to secure low relative humidities, but the apparatus would be somewhat expensive both in installation and in operation. The apparatus finally chosen for the Forest Products Laboratory Propeller (rooms) is automatic in its operation. It is capable of acting either as a humidifier when the humidity is below the value desired, or as a dehumidifier when the humidity is too high. The principles of operation are those of the water-spray dry kiln, which has been successfully used in commercial operations. The details of this humidity controlling apparatus were designed by H. D. Tiemann, M.E. M.F., patentee of the water spray dry kiln.

RELATIVE HUMIDITY.

In order that the theory and operation of the humidity and temperature controlling apparatus may be made clear, a short discussion on relative humidity is given.

The maximum amount of water vapor that space can retain at any given temperature is always the same. More moisture cannot be injected without condensation's taking place. Under such conditions, the space is said to be saturated. The presence of air does not interfere with the presence of the water vapor and the ordinary expression is that the atmosphere retains the water vapor. With an increase in temperature, the capacity to retain water vapor is increased; and with a decrease in temperature, the excess moisture is condensed out.

Relative humidity is the ratio, expressed in percentage of the amount of water vapor actually present in the atmosphere to the amount for saturation at the same temperature.

Since the capacity to retain water vapor increases with increase in temperature, it is possible to secure low relative humidities simply by heating the atmosphere without adding any moisture. The amount of water vapor required to saturate the atmosphere at 60° F. is only one-half that required to saturate it at 80° F. If the atmosphere be saturated at 60° F. and then heated to 80° F., without the addition of moisture, its relative humidity will become 50 per cent. If we saturate air at 41° F. and heat it to 80° F., we get only 25 per cent relative humidity. Evidently we can get any humidity we desire at 80° F. simply by choosing the temperature at which we saturate the atmosphere, and then heating it. This can be done for any room temperature; so that, in order to control the humidity, it is necessary only to control the temperature at which the atmosphere is saturated, otherwise called the dewpoint temperature, and the temperature to which the atmosphere is then heated. In Fig. 1 are shown the curves from which the dewpoint for any room condition can be determined. The curves beginning at the top of the sheet and dropping off toward the right indicate the actual water-vapor content of the atmosphere under any condition, and

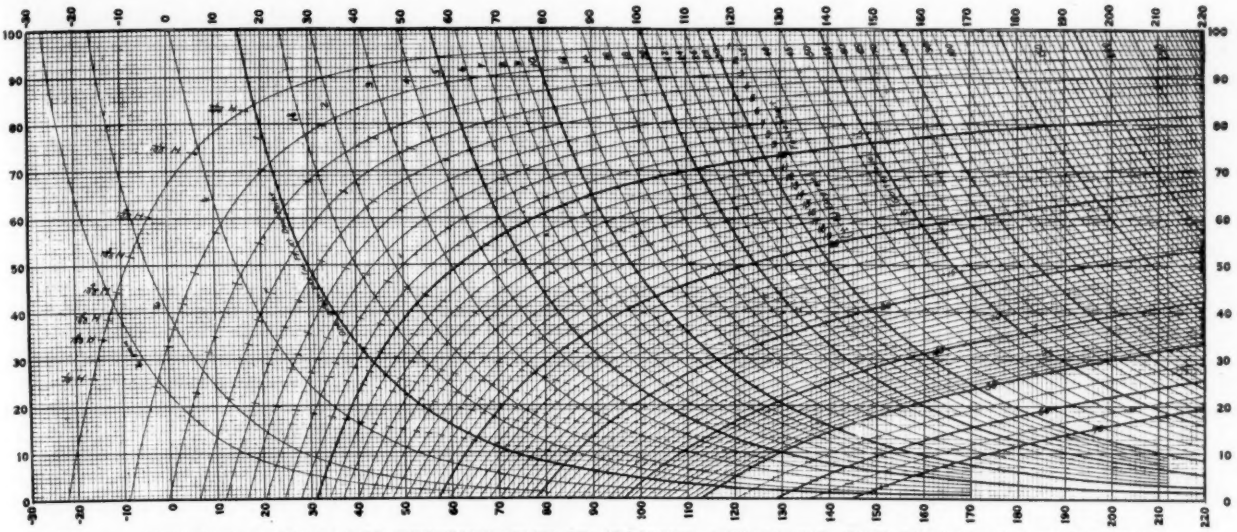


FIG. 1. HUMIDITY DIAGRAM FOR DETERMINATION OF ABSOLUTE HUMIDITIES, DEW POINTS AND VAPOR PRESSURES; ALSO RELATIVE HUMIDITIES BY MEANS OF WET-AND-DRY BULB THERMOMETER, FOR ANY TEMPERATURE AND CHANGE IN TEMPERATURE

the temperature reading at 100 per cent relative humidity is the dewpoint.

If we wish to find the dewpoint for an atmospheric condition of temperature = 90° F.; relative humidity = 65 per cent, we follow the chart as follows: At the intersection of the lines indicating 90° F. and 65 per cent relative humidity (indicated on the chart by the letter A), we find a heavy curve line rising toward the left, stopping at the top of the chart at 77° F., the dewpoint of saturation temperature for that atmospheric condition.

PRINCIPLE OF HUMIDITY CONTROL.

It has just been shown that, if air is cooled to the dewpoint temperature for a particular atmospheric condition and is saturated, the amount of water vapor retained is fixed. It is important that this shall not be changed, or else a different humidity will be secured. Consequently, the air must not be cooled below the dewpoint temperature after being saturated, or some of the water vapor will be condensed out. Nor must moisture enter the air from outside sources after the air is saturated, or higher humidities will result. After the water-vapor content of the atmosphere has been controlled by cooling to the dewpoint temperature and saturating, the air is passed through heating units which bring it to the temperature desired, and the conditions have been controlled.

After entering the room, the air is subject to changes. Heat and moisture may be absorbed or given off by the material in the room, or may pass through the walls of the room. Since, in either case, the air must be conditioned again in order to keep the room under control, the air is circulated through the controlling apparatus again and brought into the room to compensate for the heat and moisture changes. The capacity of the controlling apparatus must be large enough to move the air as fast as changes take place in the room.

CONTROL OF THE DEWPOINT.

The dewpoint temperature is controlled by passing the air through a spray of water, which both cools and saturates the air. Fig. 2 shows the arrangement of the sprays in the chamber. A line of spray nozzles is placed about 12 inches below the top of the chamber, and water is forced through the nozzle at about 40 pounds pressure, giving a fine spray, which drives the air through the chamber. The water leaving the nozzles must be several degrees cooler than the dewpoint temperature, since it absorbs heat in cooling the air that is passing through. The temperature of the spray water can be regulated by a mixing valve, supplied with hot and cold water at the same pressure, which can be set to supply water to the sprays at any intermediate temperature.

The spray chamber is of waterproof material, preferably of non-rusting metal, and is provided at the bottom with a drain, through which the spray water is carried off. Since the temperature inside the spray chamber, namely, the dewpoint temperature, is lower than the room temperature, the front of the chamber is covered with a heat-insulating material to prevent the cooled air from absorbing heat before it leaves the chamber.

The lateral depth of the spray chamber is kept small enough to prevent back currents of air, which might carry a mist out of the top. The spray carries the cooled and saturated air to the bottom of the chamber where it passes through baffles. These baffles, fitted with sharp lips, remove the entrained moisture from the air, preventing supersaturated air from passing through.

The temperature at which the air leaves the baffles determines the amount of moisture retained, and a thermometer, placed in the path of the air as it leaves the baffles, measures the dewpoint temperature. By placing the thermometer at this point, errors due to heat losses in the spray chamber are eliminated.

The air is carried from the baffles to the heating coils by ducts, which must be waterproof, to prevent moisture entering from outside sources, and must be as warm as or warmer than the dewpoint temperature to prevent condensation as the air passes through. If the duct is warmer, the air will absorb heat, and the water vapor is certain to be retained. These precautions are taken to bring the saturated air from the spray chamber through the heating coils without a change in water-vapor content.

TEMPERATURE CONTROL.

Upon leaving the duct, the air pases through heating coils of sufficient capacity to bring the temperature up to the value desired for the room. The air absorbs heat and, as it rises, influences a thermostat placed 3 or 4 feet directly above the heating coils. The thermostat operates on the steam supply, allowing sufficient steam to enter the coils to heat the air to the desired temperature, and cutting off the supply when the temperature gets too high. The temperature of the air in the room is controlled within one degree of the setting on the thermostat. The thermostat can be set for any temperature within a practical range, and this makes flexibility of control possible.

The radiation of heat and the passing of moisture through

the walls vary with seasonal changes, affecting the conditions of the atmosphere within the rooms. This may be compensated for in part by using small heating coils during warm weather and larger coils during cold weather. The heating unit may be broken into subunits, and only as many subunits as are necessary need be used. Thus closer control is made possible.

CIRCULATION.

The conditioned air is circulated by two means: first, through the force of the sprays; and, second, through the room by fans, placed above the heating unit, which take the air as it leaves the coils and distribute it through the room. If the room is being used to control the moisture content of wood, the air may largely be recirculated and only a small supply of fresh air need be drawn in. The heat and moisture losses in such a room are ordinarily small, so that it is not necessary to condition the air so often, and control is more easily maintained.

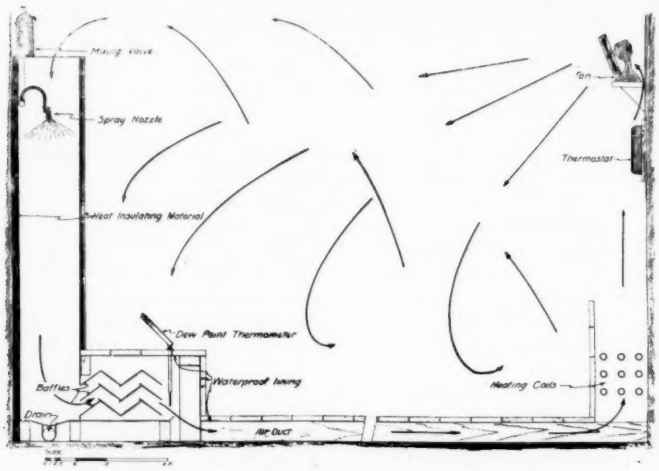


FIG. 2. ARRANGEMENT OF HUMIDITY CONTROL APPARATUS

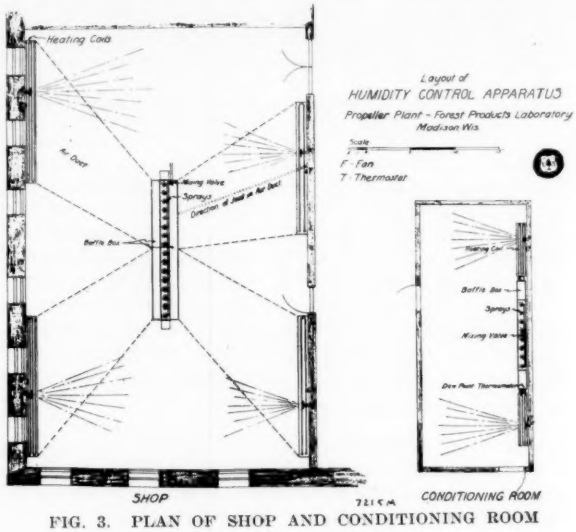


FIG. 3. PLAN OF SHOP AND CONDITIONING ROOM

It is more difficult to control atmospheric conditions in rooms where workmen are engaged, for doors are frequently opened, allowing unconditioned air to enter, and a generous supply of fresh air must be introduced for breathing. The additional changes caused by machinery and radiation require a somewhat frequent conditioning of the air.

ARRANGEMENT OF THE APPARATUS.

Fig. 2 shows diagrams of the humidity and temperature controlling apparatus. The essential parts of the apparatus are named and the path of the air is shown by arrows. Fig. 3 gives a plan of a shop room and of a storage or stock-conditioning room, showing the position of the spray chamber, heating units, and accessories.

In the shop room the air is drawn into the spray chamber from near the ceiling and is carried from the baffles to the heating coils through a duct under the wood floor. The duct, which opens out fanshape to offer least resistance to the flowing air, is painted on the bottom and lined on top with waterproof paper. Double sash windows have been put in to reduce the radiation. Fresh air is drawn in from the outside through a conductor pipe leading into the spray chamber. The arrangement in the storage room is much the same as in the shop room, except that the ducts are placed along the wall at the end of the spray chamber.

Fig. 4 shows a photograph of one-half of the metal spray chamber. The heating coils are enclosed in a wood box to prevent air from passing into the room before it is properly heated. The mixing valve, with hot and cold water supply pipes, is shown above the spray chamber. The thermostat, operating the steam valve by compressed air, is placed on the wall. The dewpoint thermometer is located above the baffle box. The dewpoint temperature for this particular room condition was only 2.5 degrees below room temperature, and no insulating material was necessary on the spray chamber.

Fig. 5 shows a wooden spray chamber, lined with waterproof paper. The front is removed and Fig. 6 shows the sprays in operation. The nozzles are set to give a fine spray, and not a mist. The water is passed through goose-necks to prevent grit from entering the nozzles.

DESIGN OF THE APPARATUS.

In workshops it is desirable to change the air once every 10 minutes. Experiments on spray nozzles have shown that, with a comparatively free air passage, one spray will move 80 cubic feet of air per minute. One spray nozzle will be necessary, then, for every 800 cubic feet of space in the room. The rest of the controlling apparatus is designed to conform to the number of sprays used. The heating coils must have capacity enough to keep the room at the desired temperature when radiation through the walls is greatest and to heat the cooled air as it leaves the baffles.

When the relative humidity desired is 60 per cent or more, the dewpoint is less than 15 degrees below the room temperature, and only a small heating capacity is required to heat the air as it leaves the baffles. As the relative humidity becomes lower, the difference in temperature increases rapidly and more heating capacity is required. The largest factor to be considered in calculating heating capacity is the amount of radiation through the walls of the room. The greater the radiation, the oftener must the air be conditioned in order that control may be maintained.

Storage rooms may be made with insulated walls so that the air need not be conditioned so frequently. Heat and moisture changes are not nearly so rapid as in shop rooms, and uniformity of control is more easily kept.

Water must be supplied to the nozzles at a pressure of 40 pounds in order to form a proper spray and to move the air through the apparatus. In order that the hot and cold water may both be supplied to the mixing valve at the same pressure, a part of the cold-water supply is diverted through a heating tank and then sent to the mixing valve.

Painting the walls of rooms prevents rapid change of moisture through the walls, and this, again, makes it easier to maintain control.

OPERATION.

Because of its ability to maintain uniform conditions, acting as a humidifier or as a dehumidifier, as the conditions

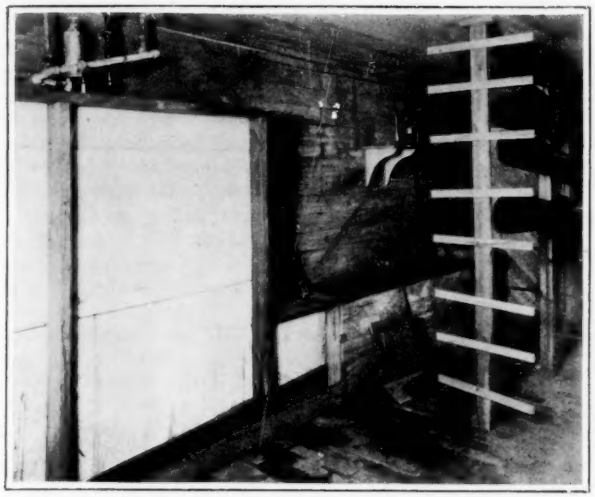


FIG. 4. ONE-HALF OF THE METAL SPRAY CHAMBER, MIXING VALVE SHOWN AT THE LEFT

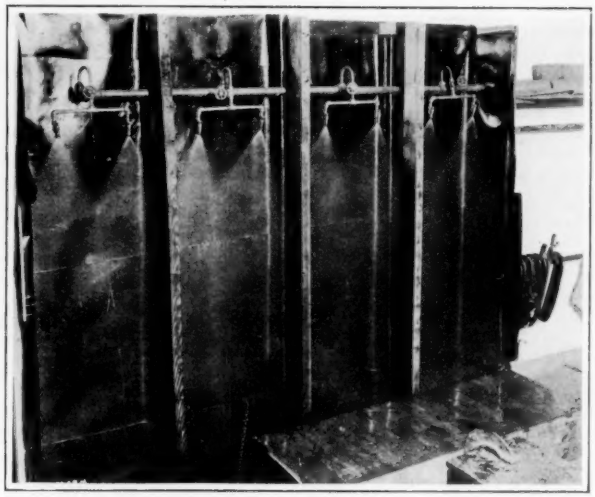


FIG. 5. WOODEN SPRAY CHAMBER LINED WITH WATER-PROOF PAPER

demand, this type of control is particularly valuable. If the air enters the spray chamber with a humidity above the desired value, the excess moisture is condensed out in passing through the sprays. If the air enters the spray chamber with a low humidity, moisture is taken up in passing through the sprays, and in either case, the air has been conditioned to the proper value when it leaves the baffles. Whether moisture is entering or leaving the room through the walls, or whether moisture is being absorbed or given off by the material in the room does not affect the operation or the control, for, in either case, the air is automatically conditioned back to the desired temperature and relative humidity, without any change or regulation of the controlling apparatus.

In Fig. 6 is shown an autographic 24-hour record for a storage room 12 feet by 30 feet by 8 feet, controlled by this system. The thermostats have kept the temperature within a degree of the desired value, and the sprays have kept the dewpoint constant, resulting in a uniform relative humidity.

An occasional inspection of the apparatus for small adjustments is usually all that is necessary. The water supply should be free from grit or scum which clog strainers and nozzles and prevent them from operating properly.

The type of installation can be suited to conditions. Where the apparatus is desired as a part of the permanent equipment, it is best that it be made of non-rusting metal. For temporary purposes only, a wooden chamber lined with water-proof paper is satisfactory. The cost of operation is almost entirely that of water supply. A work shop, 30 feet by 50 feet by 11 feet, requiring a change of air every 10 minutes, would call for a controlling apparatus with 20 sprays consuming 400 gallons per hour. Where cold water is cheaply obtained, this type of control becomes a commercially economical installation.

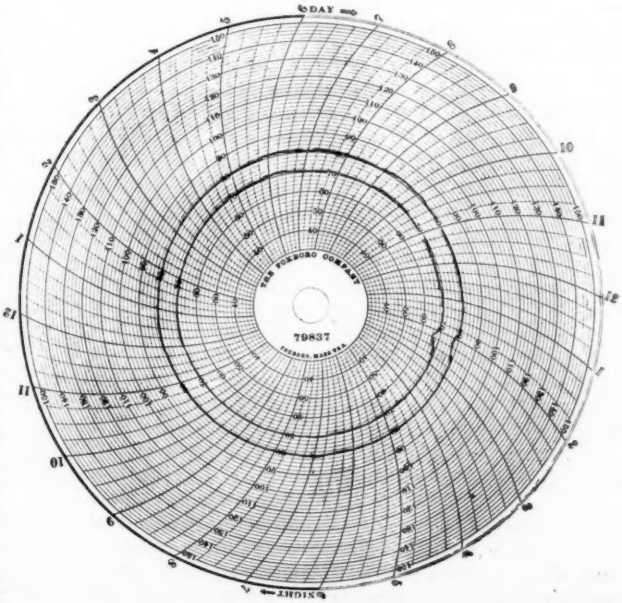


FIG. 6. AUTOGRAPHIC 24-HOUR RECORD FOR A STORAGE ROOM

The application of humidity control to commercial fields has extensive possibilities. In wood-using manufacturing establishments, where material is cut accurately to dimension, the best results are obtained when the wood is kept at a uniform moisture content after being cut, so that shrinking and swelling due to changes in moisture will have less tendency to prevent the parts from fitting together at the time of assembling.

In shops where humidity control is not practiced, even when the parts are assembled immediately, the effects of shrinking or swelling, due to unequal moisture contents, are not avoided, but become evident in the warping, checking, or even splitting of the assembly. When it is desired to minimize these effects, the wood should be conditioned before being cut to dimension.

Although kilns are instrumental in removing moisture from wood, the moisture content throughout a load may not be uniform, and the differences in moisture content on leaving the kiln may be great enough to cause trouble in the manufactured article. If the stock of material is left in storage rooms in which the conditions are controlled, the moisture content becomes uniform, and subsequent unequal shrinkage or swelling is minimized.

The conditioning of shop rooms has a double purpose. Primarily, it affords control of the moisture content while the material is being worked up into shape. Even if the material is conditioned in a storage room, the conditioning must be continued in the shop if shrinkage or swelling is to be avoided. Controlling shop conditions continues the process of making the moisture distribution uniform. As a secondary result, conditioning a shop room increases its healthfulness. Dust in the air is carried into the spray

chamber and washed away with the waste water, giving a supply of clean air in the shop. Also, the temperature of the shop room may be maintained at a uniform degree and in summer, when high temperatures prevail outside, the shop may be kept at lower and more comfortable temperatures.

Although developed primarily for use in wood-using establishments, first in the dry kiln and then in shops and storage rooms, the field of this humidity and temperature control is by no means restricted to wood-working plants. It may be used wherever for any purpose it may be found desirable to maintain definite, uniform atmospheric conditions.

Among others, conditioning control has been found beneficial both to the material being manufactured and to the health of employes in the following places: Finishing and drying rooms, textile mills, munition factories, chemical factories, foodstuff factories, rubber factories, and tobacco factories. There are numerous other important industrial plants in which control of atmospheric conditions would be beneficial and the type of apparatus described in this article would probably be applicable to many of them.

General Applications of Selenium—1*

Its Utilization in Biological Chemistry and in the Glass and Rubber Industries

By Louis Ancell

AT first glance selenium and its applications hardly seem to be properly included within the domain of industrial chemistry properly so-called. However, certain new applicaions of this metalloid either already accomplished or by way of accomplishment in biological chemistry, in chemical industry, and especially in electrical technology make it a matter of interest to consider in a single article the properties and applications—at once so original and so varied—of this substance so scantily found upon the earth and yet so well-known because of the numerous scientific works devoted to it.

We will examine in order:

1. Selenium and its principal properties.
2. The utilization of selenium in biological chemistry.
3. The employment of selenium in the glass and rubber industry.
4. The applications of selenium in electrical technology, especially in the chemical industry, the military art, the photography of words or the reproduction of sounds by photography, wireless telephony, television and the transmission of images to a distance, and photometry.
5. The future of selenium and its applications.

Selenium is best known by its curious property of having its electric conductibility influenced by exposure to light, but it is none the less true that it is capable of various chemical applications of an industrial nature, and in this respect it offers a wide field for research.

PRINCIPAL PROPERTIES OF SELENIUM.

Manufacture.—Selenium is a metalloid belonging to the sulphur family whose atomic mass is 79.1, the figure adopted in 1898 by the International Commission of Atomic Weights. It was discovered in 1817 by Berzelius in the sediment of the lead chambers of Gripsholm, the treatment required being long and complicated. The present process as applied in one of the principal chemical works in France, consists in extracting the selenium from the residuum left by the treatment of the Hautmont (Nord) pyrites, titurating about 15 per cent. These residues are first treated with *aqua regis* which transforms the selenium into selenious acid. This latter compound is reduced by suphurous acid which precipitates the selenium in the form of a powder which is then washed and dried. Finally the product is melted and run off in the form of cylinders in copper molds immersed in water; it is placed upon the market in this state.

Selenium can also be extracted from zorgite and the impure double seleniide of copper and lead which is tolerably abundant in the Argentine Republic, and which contains nearly 30 per cent of selenium. In this case the pulverized mineral is treated with *aqua regis* which transforms the selenium into selenious acid and the metals into chlorides. The excess acid is driven off by evaporation and the sirupy liquid is then diluted with water in order to precipitate the major portion of the chloride of lead. After filtration the clear liquid is treated by a current of sulphurous gas which precipitates the selenium in the form of red flocculae. It is filtered again and washed with hydrochloric acid and with water to eliminate the last traces of chloride and is then melted in black lead crucibles and run off either in sheets or in cooled molds.

It is of importance, especially with respect to the physical applications of selenium, to purify it in order to eliminate the sulphur and the tellurium which it always contains. One of the most practical methods of doing this appears to be that of Divers and Shimosé[1] since this permits a rapid and practically complete purification. In this process the selenium is dissolved in boiling concentrated sulphuric acid and is thus transformed into selenious acid. The cooled liquid is afterwards diluted with water and then treated with a current of sulphurous gas which precipitates the selenium. The red powder obtained is separated by filtration, washed with water and alcohol, and then placed to dry upon plates of porous porcelain. In this manner the traces of tellurium are completely eliminated and the purified product contains only slight traces of sulphur which are practically negligible.

Selenium presents itself in various allotropic conditions which are of interest because of their peculiar properties. A first form of these includes vitreous selenium, amorphous selenium, and colloidal selenium; a second form is red crystallized selenium; and a third form is grey or metallic crystallized selenium which is differentiated from the other two forms by the fact that it alone is completely insoluble in carbon disulphide.

Vitreous Silenium.—1. In its first form selenium melts at 220° C.; and becomes soft and viscous at about 60° C.; if it is then cooled again it becomes hard and brittle and is then called *vitreous* selenium. This is black in color with a conchoidal fracture and when powdered it is grayish if the powder is coarse, and red if it is very fine. In the course of our researches (begun in 1909) concerning this variety, we found that vitreous selenium melted at 220° C. and when cooled rapidly *under pressure* is suddenly transformed into a new variety, *violet* gray in color and composed of fine crystals which are highly sensitive from the photo-electric point of view, but whose stability leaves much to be desired. In order to utilize and preserve this extra sensitive variety, consequently, it is advisable to add to it a certain quantity of vitreous selenium in order to distribute uniformly the violet gray crystals in a sort of solid and stable solution of vitreous selenium. The latter constitutes a substratum which cements and re-

*Translated for the SCIENTIFIC AMERICAN MONTHLY from *Chimie et Industrie* (Paris).

[1]Divres and Shimosé, Chemical News, Vol. 51, p. 199, 1885.

unites the various sensitive crystals of the upper stratum which is exposed to the light. Accepting this explanation which appears to be more or less plausible but which is given here merely by way of suggestion, we succeeded in discovering a process which enabled us to make a practical preparation of selenium cells which are extremely sensitive even to the feeblest luminous intensities. On the other hand the slightest impurity (particularly metallic powders) constitutes a sort of poison, which while activating the transformation causes the destruction of the unstable variety of sensitive crystals and transforms the mass of selenium into a variety which is as good a conductor as a metal, and is furthermore insensitive to light.[2] This modification is also capable of being produced in the cells by the mere lapse of time, or under some external influence such as the sudden passage from heat to cold or vice versa, a somewhat violent shock, or a sudden break of a circuit containing a self-induction and the cell. It is obvious, therefore, that very great precautions must be taken in the preparation as well as in the employment of this variety of highly sensitive selenium.

Amorphous Selenium.—Also included in the first form of the allotropic state is *amorphous selenium*, which is obtained in the state of a red precipitate through the reduction of selenious acid by sulphurous gas. Heated to a temperature of 40° C. to 50° C. this red powder becomes agglomerated into a soft mass, which becomes hard and brittle when cool.

Colloidal Selenium.—Colloidal selenium, the third variety of this first form is obtained by mixing two very dilute solutions of selenious and sulphurous acids. The mixture, which is yellow at the beginning, gradually turns red and finally deposits a red powder of selenium, insoluble in water, which becomes agglomerated at 40° C to 50° C., and is transformed like the amorphous selenium, and under the same conndition, into vitreous selenium.

Crystallized Red Selenium.—2. This constitutes the second form of the allotropic state. It is not sensitive to light and is obtained by the slow and careful evaporation of a sulphocarbonic solution of selenium.

Crystallized Selenium.—3. Finally *gray or metallic crystallized selenium* is obtained by the action of heat upon anyone whatever of the foregoing varieties. This according to Saunders[3] is the form which is most stable at all temperatures below 217° C. to 220° C., the point of fusion of selenium. This variety is not soluble in the sulphide of carbon, no longer exhibits a conchoidal fracture, and assumes a granular aspect; it is a conductor of electricity especially under the influence of light or of a slight elevation of temperature.

The density of selenium varies from 4.259 to 4.805 in the different varieties.[4]

The average boiling point of selenium is about 690° C. as proved by Daniel Berthelot.[5]

Vitreous selenium which is not a conductor of electricity is transformed as we have seen under the influence of heat alone into the metallic conducting modification, or under the combined influence of heat and pressure[6] into a modification which is an even better conductor of electricity than the ordinary metallic variety. This conductibility is highly augmented when the selenium is mixed with metallic powders. It is well to note, also, that the heating of selenium in order to obtain a highly sensitive variety should be made with a care to exclude both humidity and a direct gas flame.

The augmentation of the conductibility appears to be due to the presence of metallic selenlides according to the researches of a number of authorities (Graham Bell, 1880, Schuller, 1883, and Bidwell, 1891), corroborated by our own investigations. When these seleniides are formed upon the surface of wires or of sheets the conductibility is normal; when, on the contrary, a few fragments of metallic powders or of vitreous selenium which has been melted and previously rubbed upon the metal, are mixed with pure vitreous selenium the latter is transformed under the influence of heat alone, or still more rapidly under the combined influence of heat and pressure into a variety of selenium which is so good a conductor that its conductibility approximates that of a metal. A cell sensitized under these conditions is practically unusable. As a result of this fact in constructing selenium cells it is necessary to employ a support which contains not the slightest metallic or conducting particle and which is incapable of absorbing humidity. Porcelain and certain varieties of steatite are suitable for this purpose.

The nature of the metal employed as an electrode does not appear to have any perceptible influence upon the conductibility of the selenium. Platinum has the advantage of not being readily oxidized and copper or even brass can be readily used in practice.

We may mention here that a collation of all the researches devoted to selenium has been undertaken in various quarters (Amaduzzi, 1904; Marc, 1907; and Ries, 1908). The Russian journal *Questions de Physiage* for 1910, page 175, contains a résumé of the principal results obtained.

THE UTILIZATION OF SELENIUM IN BIOLOGICAL CHEMISTRY.

Silenium alone has hitherto found but little employment in chemistry worth mentioning from the industrial point of view. But it has been used for several years in the form of cutaneous injections in mice at the Institut Pasteur by M. Borel, in certain bilogical researches relating to the development of cancer. It has been thought that the toxicity of selenium and of its salts might occasion a retrogression of the tumors. As a matter of fact, however, the experiments made upon mice have not yielded conclusive results and no tests have been made upon human subjects. So far as we know no new researches have been attempted along this line.

SELENIUM IN THE GLASS AND RUBBER INDUSTRIES.

Selenium has been employed in the manufacture of glass, giving a pale violet color and more recently in the vulcanization of rubber.

In the first case the selenium is incorporated with the molten glass, either in the form of vitreous selenium or under that of selenites which undergo reduction during the manufacture of the glass.

As regards the latter use experiments have been conducted in Boston since 1913 by the Simplex Wire and Cable Co. In these experiments a quantity of selenium equal to that of the sulphur employed in ordinary vulcanization is heated to 150° C. for two hours' time. The product obtained is somewhat less solid from the mechanical point of view than the rubber vulcanized by sulphur. On the other hand it is possible to obtain selenium rubbers which are soft and very durable and which exhibit excellent resistance to normal traction and extension by heating the selenium to 135° C. together with certain organic accelerators for a period of time twice that of ordinary vulcanization.

This selenium caoutchouc does not deteriorate in spite of the sensitiveness of selenium to light.

(To be continued)

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[2]Louis Ancel, Bull. de la Soc. Chimique (Chemical) de France, fourth series, Vol. xvii, p. 10, 1915.

[3]Saunders, Jour. of Phys. Chem., Vol iv, p. 423, 1900.

[4]Schaffgotsch, Journ. f. prakt. Chm. Journal of Practical Chemistry), Vol. xliii, p. 308, 1848.

[5]D. Berthelot, C.R. Ac. Fr., Vol 134, p. 705, 1902.

[6]Louis Ancel, Bull. Soc. Chim. l.c.

NEW USES FOR "CELLON."

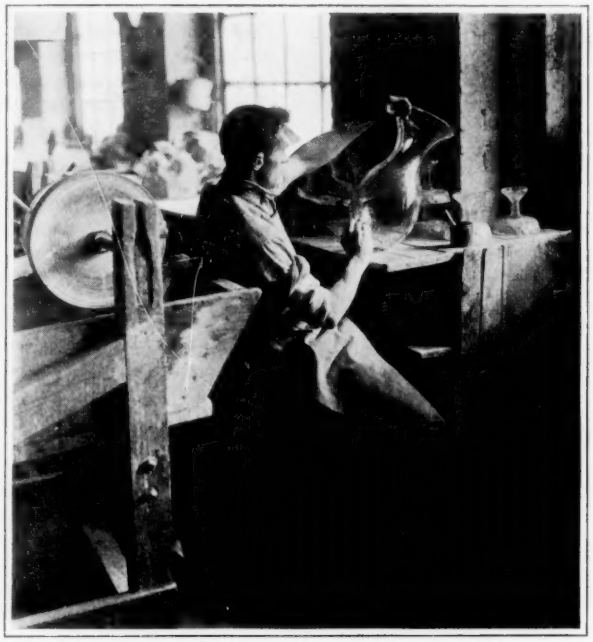
LIQUID "Cellon" can be used for impregnating textiles, etc., or for making insulating tape. In this latter form it can be taken from the round box in which it is wound up, even in the moist condition, and allowed to harden in air.—Abstracted through *The Technical Reviews* from *Mitteilungen des Reichsbundes Deutscher Technik*, Aug. 30, 1919.

Modern Glass Manufacture

American Methods of Making Cut Glass

By J. F. Springer

GLASS is, I think, one of the most wonderful of all the materials prominent in modern civilization. When one considers the beautiful clear transparency attainable with glass and the readiness with which the transparent substance may be shaped to an infinity of forms, he begins to realize some of the remarkable qualities. When one goes further and takes into account the immunity that glass enjoys with respect to the attacks of pretty much all acids and chemicals of every sort, he is still further impress d. The foregoing qualities, taken in connection with its cheapness, make of it one of the most popular and useful of all the materials used for household, laboratory, pharmaceutical and building purposes. Tableware, chemical appliances, medicine bottles, window-glass—all these are prominent examples of the application of glass. This material is usually very fragile, brittle and hard. But those qualities vary between limits that are fairly wide apart. Glass is ordinarily, but not always, transparent. Because of such variations as those noted, it is not so easy to give a descriptive definition that will sufficiently distinguish it from other substances. There is, however, one quality which assists us in marking it off and giving it a place of its own. Glass is structureless. Doubtless, from the point of view of chemistry, there is structure. Generally, minerals and bodies of the types associated with life processes have a crystalline or other structure. With glass, there is apparently no such thing as a structure that can be made evident by the unaided eye or by means of the microscope. Glass seems, in fact, to be as structureless as any of the liquids—as water, for example. If one chooses to regard glass as a "congealed liquid," he may do so, provided he does not assume anything in the nature of crystallization. However, W. Rosenhain, an authority on the manufacture of glass, says: "All glasses are capable of undergoing the change to the crystalline state when kept for a sufficient time at a suitable temperature. The process which then takes place is known as 'devitrification,' and sometimes gives rise to serious manufacturing difficulties."



LAYING ON THE PROPOSED PATTERN WITH A PENCIL

In general, glass may be viewed, when in the molten state, as a mutual solution of silicates and borates. The condition of mutual solution continues throughout ordinary cooling, so that one is privileged to regard glass in the cold state as a congealed solution. The substances which enter into the composition of glasses have, naturally, their individual melting points, so that if the temperature of a mass of molten glass be maintained for a period at a little below the fusion point of one of the constituents, that substance may often begin to solidify alone and its crystals to take form in the mass. This is a devitrification process, and is something to which certain glasses are especially subject.

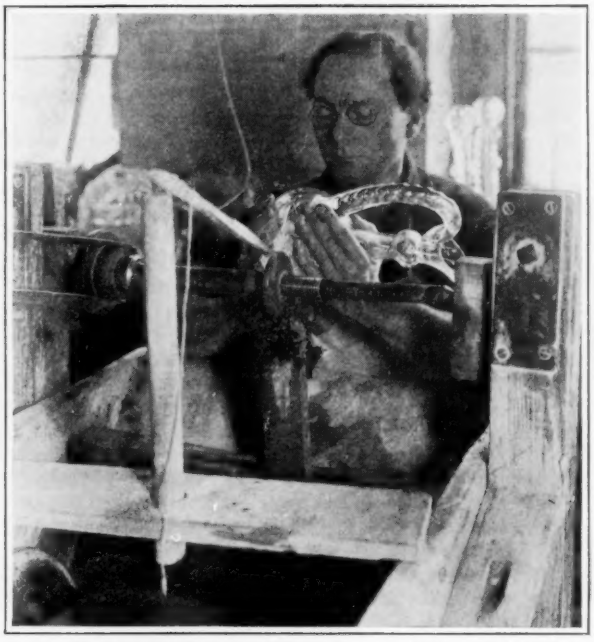
It is a fact well recognized that the presence of impurities in a substance often tends to lower its point of fusion. This is true of glass. Pure silica may be made into a glass of a very valuable kind, but the temperature necessary to effect the fusion of the pure substance is so great that the ordinary furnace of the glass-maker is quite inadequate. The laboratory furnace heated by the oxy-acetylene flame is, however, usable; although a less perfect silica ware is producible by means of the electric furnace.

Glass is dependent upon the materials which are brought together in the mass which is reduced to the molten state in the crucible employed—but it is not entirely dependent upon these materials. That is to say, during the period of melting, the molten mass will absorb from the fire-clay crucible. The mutual solution constituting the molten mass tends, it is understood, to a condition of saturation, so that it will seek to rectify any deficiency by absorptions from the containing vessel. Because of this fact, it is customary to choose the precise character of the material in the body of the crucible with a view to such absorptions. For example, if a crucible charge is rich in silica, an acid substance, but deficient in bases, the mass when molten will naturally dissolve basic material from the crucible walls. Similarly, if the charge is poor in acid materials, it will tend to absorb substances from the fire-clay container.

A certain glass, which is rather difficult to make because of its considerable fusion point, is termed "combustion tubing." This tubing meets the desire for a glass capable of retaining its hardness without much loss when it is heated to a red heat. Instances of such glass are the varieties known as Jena special thermometer glass, and the French "Verre dur." The highest qualities of refractory glass are competent to resist temperatures up in the neighborhood of 900° F. Combustion tubing is manufactured from a glass containing a much reduced percentage of basic material. The alkaline material is especially minimized. What basic material is used is selected from the highly refractory bases, such as lime, magnesia, etc. Special furnaces are needed to effect the melting.

The molten mass in the crucible or furnace is removable in three ways—and, it seems, in three ways only. These are (1) by means of a ladle; (2) by pouring, and (3) by gathering. The most objectionable of these is the first. The metal of the ladle communicates impurity both to the glass withdrawn in it and to the main body into which it is dipped. Further, the cold ladle carries with it a considerable quantity of small particles of air; or, perhaps it would be more

PARAFFINING THE INSIDE OF A BOWL BEFORE DIPPING IT INTO THE ETCHING BATH



CUTTING OUT THE PATTERN IN A CLARET DECANTER WITH A CARBORUNDUM WHEEL

correct to say that the ladle carries in air which manifests itself as small bubbles in the body of the glass. A hot ladle might perhaps avoid this phenomenon, but it would introduce another objectionable result—the adherence of glass to the metal. This disadvantage must be ranked by the manufacturers as very undesirable indeed, since cold ladles are in such general use, despite the air-bubbles and the additional objectionable feature that the cold ladle chills the glass in immediate contact with its inner surface. Ladling is, in general, confined to those cases where the glass is to be used for such purposes where the bubbles will not find objection. Such glass is, naturally, inferior in quality. It is, however, quite serviceable for certain applications—especially window-glass of inferior grades. Ladled glass is usually rolled. That is, it is thrown upon a level surface and there rolled by a roller which passes over the surface; or it is passed between two rollers set in fixed positions and is received subsequently to emergence by a moving table. This latter variety of rolling is especially used in producing figured rolled plate, the figures consisting of indented patterns.

The higher qualities of glass are removed from the crucible or furnace by pouring or gathering. Thus, cut glass is made from material withdrawn by one or other of these methods; and seldom or not at all from material removed by the ladle. The explanation is simple. When glass is cut for the purpose of ornamentation, a greater or less amount of work is put upon it which tends to increase the price. Consequently, the expense means close scrutiny upon the part of the customer. Pouring is accomplished by tipping the containing crucible or pot. This receptacle may be the one in which the original melting took place; or it may be a special pot to which the glass has previously been transferred. In either case, the highly heated pot with its charge of molten glass may require to be taken out of the furnace by mechanical means. Overhead machinery may now be called into action for the purpose of transporting the pots to the spot where the pouring is to take place. The pot is tilted and the glass runs out. What now becomes of the glass depends upon the particular method of manufacture. In one procedure, the molten glass flows from the pot upon a rolling table and a roller is passed along to roll out the pool into a sheet or thin slab.

Instead of pots, it is often, not to say generally, preferable to use what is known as a tank furnace. In a work on glass manufacture dated 1908, the author stated with reference to tank machines: "None of these devices have, so far as the writer is aware, found their way into practice." In a U. S. Government report dated 1917—only nine years later—it is stated: "The tank furnace has generally displaced the pot furnace. The advantages claimed for it are increased production, continuous operation, regularity of work, more efficient utilization of the heat and flame of the furnace, greater durability, and better glass production, in that the molten glass in a tank can be maintained at or near a constant level, which makes gathering easier."

There are machines which dispense with gathering and substitute pouring or flowing. Thus, there is a type of mechanical device which is adapted to receive molten glass into molds which revolve. In the case of a certain machine of this type, the revolving molds will pass below a certain point. Here there will be a projection from the tank. A stream of glass flows vertically downward as the molds pass. There is, at one side of this vertical stream, a cup-shaped cutter, and at the opposite side, a blade. The cutter and the blade are operated horizontally in such way as to come together, after the manner of the blades of a pair of scissors. The result is that the vertical stream of glass is cut off. It continues, however, to flow into the cup-shaped cutter instead of passing on into the mold. The cup affair is turned over part way, but not so far as to prevent the glass from the tank from flowing into it. The next mold now comes into position, and the glass caught by the cup device is delivered to the mold. "The stream of glass from the tank then flows directly into this new mold." The cycle of operations is repeated as each mold comes to position. These machines are not used for all purposes. In fact, their applications appear so far to be rather limited. They are particularly suited to jars and to bottles with wide mouths.

The third method for removing glass from the furnace or crucible proceeds by using a heated iron rod or tube. The rod or tube is introduced into the mass of liquid glass and gathers a small amount. It is then withdrawn and the glass permitted to cool to the point that it is able to support its own weight. The rod or tube with its ball or knob of partially cooled glass is now introduced into the molten mass and

additional material gathered. The cooling is repeated. By going through this procedure a number of times, a considerable amount of glass—up to 30 or 40 pounds—may be gathered. The process is suitably known as gathering.

Perhaps the most interesting side of the glass industry is that which is concerned with the manufacture of cut glass. The interest of Americans will not be diminished by the fact that the heavy cut glass manufactured in the United States is thought to be superior to similar cut glass manufactured elsewhere in the world. Superiority is claimed particularly in respect to the crystal brilliancy and to the sharpness of the cutting. Oxide of lead and potash have been largely employed in making the glass. The potash facilitates the fluxing of the other materials which enter the furnace. Both the potash and the lead oxide produce "a prismatic effect with high refractory qualities." So beautiful and artistic are the best grades of American cut glass that its reputation has spread throughout the world. Permit me to repeat from a grave Government document a story illustrative of this point: "Some people accustomed to traveling abroad are inclined to believe that cut glass from Europe is superior in quality to the best American product. An American manufacturer of cut glass who has a salesroom in New York City informed an agent of the Bureau of Foreign and Domestic Commerce that two years previously a wealthy woman called at the factory and showed him a glass article which had been broken. She stated that she had purchased the set at one of the fine shops in Vienna and inquired whether this company had not imported a similar set from which the broken article could be duplicated. The manufacturer examined it closely, and informed her that his salesroom in New York had a similar article in stock and that it would be shipped to her. The cut-glass products of this factory had been exported in considerable quantities to Austria-Hungary, and the broken article that was duplicated had really been made in the American factory."

Cut glass is manufactured from blown blanks or else from pressed or molded blanks. The latter type of blank may come from the press-molds with a considerable part of the desired pattern already formed. There are, naturally, various grades of quality. Where the cutting is shallow and has been effected merely by the use of the common unpolished wheel engraving, the cost of certain small articles may be such as to permit their sale in 5 and 10 cent stores. Then, on the other hand, the designs may be most elaborate and belong to the class known as "rock crystal." The cutting and engraving of such articles as vases, stem ware, colognes, etc., is generally carried out on blown blanks. Apparently, the principal reason is that such forms are unsuited for production by the mold. Where the form is open—that is, where the pieces are bowls, plates, etc.—the pressed blanks are usually employed. As to designs, it is said that there are many more original designs used for American cut glass than for European and that many American designs are taken abroad and there initiated. Going back to the normal period before the outbreak of the Great War, one learns that Europe imported American cut glass in considerable quantity. The countries to which the exports went included "countries that produce deep-cut glass and that have high duties on their imports."

In typical high grade manufacture, there are three principal operations. First, the cut is made by means of a steel wheel. The glass article is held against the rotating wheel and sand and water are poured on the wheel. Second, the article is held against a rotating stone wheel. This wheel smooths out the rough cut made by the steel disk. Two varieties of a Scotch stone known as Craighleith are employed. One is black in color and is softer than the other which is white. The soft black stone is preferred. Third, the article is held against a rotating felt wheel. The effect here is to produce a polished surface. The initial or roughing operation is often eliminated by the use of suitably figured blanks produced by a press-mold. This procedure effects also another saving. That is to say, it is then unnecessary to mark the pattern on the blank. However, the production of figured blanks was—and perhaps is still—accomplished by a patented process. Plain blanks had to be used by factories not participating in the patent. These were produced by iron pressure-molds or else blown in the ordinary way.

American methods differ somewhat from European. In general, in the United States, a big manufacturer will use different workmen for the three operations. In Europe, one man often carries out all three. Naturally, the American workman becomes highly expert on his single operation. Where the lines of the design have a considerable radius of curvature, it is permissible to use large wheels. There is an American tendency to favor such designs rather than those which contain sharp curves for which small wheels must be employed. American manufacturers use, in the smoothing operation, carborundum wheels and carborundum powder or grains to a considerable extent instead of following the European practice of employing stone wheels and sand. In Europe, the polishing is usually performed by means of the felt wheel and putty powder, while in America the article is dipped in acid subsequently to the smoothing operation. This preparation for the polishing is understood to result in the maintenance of the sharpness of cut; whereas, hand polishing with the felt wheel and putty powder tends to dull the cuts. The people in Europe have not been educated to the beauties of deep-cut glass ware, since—at least, until recent years—they preferred thin ware. But their education is progressing. An importer who sold Alsatian ware in the United States made substantially the following statement: "Five years ago I saw a window full of American deep-cut glass in Strassburg, the capital of Alsace-Lorraine. After that, I quit trying to compete in New York with American cut-glass."

ELECTROLYTIC COPPER.

"COPPER from Mine to Finished Product" is the subject of a very instructive brochure issued by the Anaconda Copper Mining Company. Much of historical interest is given as well as descriptions of commercial processes, and the following paragraphs on the electrolytic refining of copper are quoted:

"The electrolytic refining of copper may be divided into three stages:

"1. Melting the 'Blister Copper' and casting into 'Anodes' ready for the electrolytic tanks.

"2. 'Electrolytic' refining and obtaining 'Cathode Copper' of 99.98% purity.

"3. Melting of 'Cathodes' and casting the commercial shapes, such as 'Wire Bars' for wire mills, 'Cakes' for rolling mills, 'Ingots' for the brass and alloy manufacturers, etc.

"The 'Blister Copper' is delivered to the refinery in the form of slabs, weighing about 300 pounds. These are melted in reverberatory furnaces, known as 'Blister Furnaces' of 500,000 pounds capacity. The details of the operation are practically the same as in the 'Refining Furnaces.' In this melting process but little refining is attempted although some of the impurities are removed with the slag and the sulphur is practically eliminated. The copper is cast into 'Anodes' 37 × 28 × 1 5/8 inches, weighing about 500 pounds. A typical assay of 'Anodes' follows:

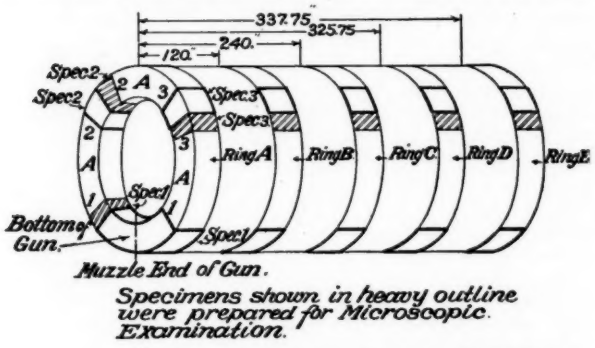
Copper—	99.25%	
Silver—	70.0	ounces to the ton
Gold—	.25	ounces to the ton
Arsenic—	.060%	
Antimony—	.052%	
Nickel—	.050%	
Lead—	.053%	
Iron—	.058%	
Bismuth—	.003%	
Sulphur—	.004%	
Selenium—	.008%	
Tellurium—	.038%	
Oxygen—	.100%	

The Death of a Big Gun

A Study in Erosion

By Arthur Benington

ARTILLERY of all sorts is short lived, and the bigger and more powerful the gun the shorter is its life. As in human life we should "count time by heart-throbs," so in common life we must count it in shots. A man is not living when he is in a state of coma, nor is a cannon living when it is not firing. A cannon begins to die with its very first shot, for this commences the work of erosion, which progresses with each shot until the bore of the gun is so worn that the projectile no longer fits it tightly; the gases generated by the explosion escape around the sides of the shell, failing to exert their full force upon it; the lands of the rifling are no longer true, and therefore cannot impart to the projectile the precise velocity of rotation that will carry it direct to its mark. Accuracy of aim is now impossible, and the gun's life of usefulness is at an end. It is true that it can be relined, and more than once, but this is a major



RELATIVE LOCATION OF RINGS IN THE GUN AND DISTANCE OF EACH FROM THE MUZZLE

operation for which the gun must be moved from the front and placed in hospital in the hands of expert surgeons, and the cost of relining a cannon three times is practically that of a new gun.

When we consider the enormous cost of cannon and how quickly the hard steel of its rifled bore is destroyed, we shall appreciate the importance of learning precisely what takes place within the firing chamber, in order that metallurgists may have the data necessary to a study of new methods of hardening and toughening the metal and thus prolonging the life of the gun. Rear Admiral Ettore Bravetta of the Italian navy has just published a book on artillery, in which there is a highly interesting chapter entitled "The Life and Death of a Gun." In this he states that before the war the British naval authorities considered guns eroded to the point of uselessnes, according to the following scale—the figures, of course, being averages: 100 mm. gun, after 739 shots; 127 mm., after 640; 152 mm., after 395; 203 mm. howitzer, after 254 shots; 234 mm. howitzer, after 204; 254 mm. howitzer, after 162; 305 mm. gun, after 149; 343 mm., after 102; 406 mm., after 83.

"Small artillery," continues Bravetta, "can fire from 4,000 to 7,500 shots; guns whose initial velocity is small, such as mortars and howitzers, last much longer than cannon of the same calibre, as they are subject to lower pressures and temperatures. Again, three shots with reduced charge equal one shot with full charge, as regards erosion."

Erosion manifests itself in the hardening and cracking of the rifled surface. The accompanying photographs, from the Bureaus of Ordnance of the U. S. Army and Navy show beautifully the appearance of this surface after a number of shots have been fired. The hardened layer is so thin that it has not been found possible to remove it for chemical analysis. The depth of this layer varies from 0.0004 inch close to the muzzle to 0.0015 inch at the beginning of the rifling, this in an American 12-inch gun that had been fired 239 rounds. The cracks, as is evidenced from the photographs, extend through the hardened surface layer and relatively far beyond it.

In the report of Gen. William Crozier, as Chief of the Bureau of Ordnance, U. S. A. for 1913, is a study of the gun just mentioned. From this five rings were cut, one at the muzzle, the others 120 inches, 240 inches, 325.75 inches and 337.75 inches, respectively, from the muzzle. From each of these rings "sections the width of each ring and of a length corresponding to about four grooves and five lands were cut." These sections are shown in the accompanying photographs, marked A, B, C, D and E. "The surface erosion was greatest in Section E (that nearest to the breech), and diminished progressively toward the muzzle end. In Section E there has been a very considerable flow of metal, and the cracks do not appear to be so numerous as in Section D. In Section D there are not only extensive transverse cracks, but also very extensive longitudinal cracks, the latter being particularly noticeable at the bases of the lands. In Section C there is no pronounced direction to the cracks, but the lands and the central portions of the grooves show a crackled appearance. In Section B the cracks are not so evident. There is some rounding of the lands, and the driving edge shows some cracks. In Section A the lands and the grooves are clean-cut, with cracks only on the firing edge of the lands."

The dimensions of these cracks vary irregularly, the greatest depth being in Section D, where six were measured as follows: 0.036″, 0.051″, 0.030″, 0.033″, 0.042″, and 0.029″. At their mouths the cracks varied in width from 0.015″ to 0.001″, and halfway back from 0.001″ to 0.007″. The cracks in Section C are only a trifle less deep than in Section D, but not nearly so wide. They get progressively smaller as the muzzle is approached.

There are three theories on any of which it is possible to account for this hardening and cracking of the rifled surface.

"In a general way," writes Admiral Bravetta, "one may say that it is produced by the action of gases at high pressure and elevated temperature upon the steel. Although this phenomenon lasts a very brief time, yet the cannon in firing absorbs a certain quantity of heat, limited to a very thin layer of steel on the surface of the bore. The local heating causes this layer to expand, but, as it is surrounded by the thick and relatively cold walls of the inner tube, such expansion cannot take place naturally, the limit of elasticity is overpassed and permanent distortion follows.

"When the pressure ceases and the temperature is lowered, the layer in question contracts and, as it has been crushed, its contraction produces a quantity of little surface cracks like those which create the value of certain precious Chinese porcelains called 'crackled.' This process continues with every shot, and each time the cracks become wider. As they increase they become so many tiny canals through which the hot gases penetrate and in their turn enlarge them. Continuing thus, the inner surface becomes rough and covered with tiny holes, while the lands begin to flatten out, to be 'eaten.'

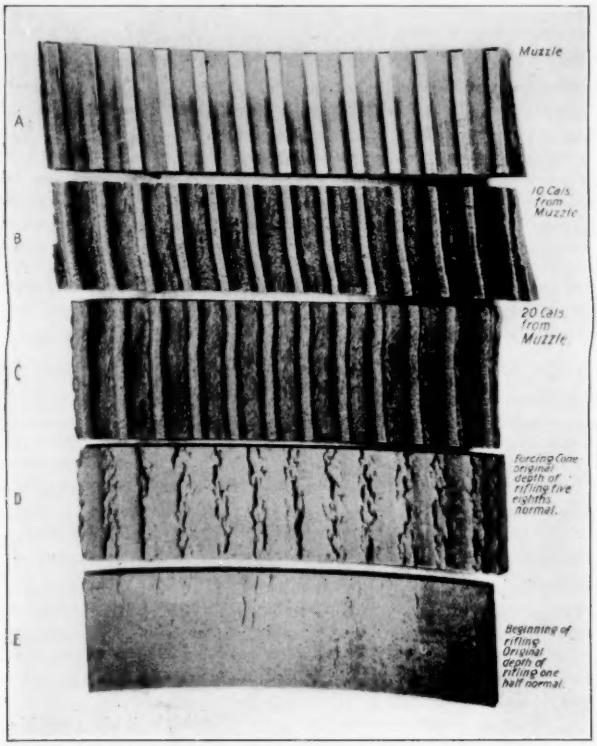
"Some persons compare the action of the gas upon the steel to that of the frosting of glass with sand, but it is not a case of merely mechanical action, for guns are eroded most

rapidly by the powders that develop the greatest heat in burning, those with a base of nitro-glycerine. These, in truth, bring about the fusion of a thin layer on the surface of the bore, and therefore it is more accurate to compare, as some do, the action of the gases on the steel to that of a jet of steam or hot air upon a piece of ice.

"The English metallurgist, Robert Austen, who made experiments on a 12-cm. cannon, which he cut off at 4.25 meters from the mouth, that is to say close to the breech, the cannon being 4.95 meters long, reached the following conclusions:

"(a) As regards the mass of the metal, the action of the explosive was purely and simply mechanical; the particles of metal were profoundly eroded, but no formation of martensite had taken place, which means that the nature of the metal had remained unchanged.

"Martensite is a sort of allotropic condition of the metal,



FIVE SECTIONS FROM A 12-INCH GUN AFTER FIRING 239 ROUNDS
From the Bureau of Ordnance, U. S. Army

which manifests itself more or less when this undergoes tempering, and which destroys itself—meaning that the metal becomes ordinary steel again—following a sufficiently long reheating and a refusion which, as is well known, destroys the temper and brings the metal back to the state of soft steel. A piece of tempered steel contains diffused through its mass a certain quantity of martensite; on reheating it a little to soften it slightly a part of this is destroyed; a longer reheating increases this destruction, which becomes complete when the action of the heat is prolonged sufficiently to make the temper entirely disappear.

"(b) On the parts of the rifling that are in contact with the bands of the projectile during its passage through the tube Austen noted, on the contrary, the presence of a layer of the thickness of 0.127 millimeters in which an alteration manifestly exists, but as to whether this was lamination, puncturing, partial fusion, corrosion, etc., he was not able to pronounce decisively.

"It is well to note that Austen found these effects after only five shots, of which a 120 mm. cannon can fire 600 or 700; so by the time it has become unserviceable the aforesaid layer must have reached the thickness of a centimeter or more."

General Crozier, in the report already quoted, discusses the three theories of erosion, and arrives at a conclusion that differs slightly from Bravetta's, though he does not definitely discard any one of the theories. He writes:

"The surface may be hardened in a manner similar to the hardening of tool steel, *i. e.*, it may be heated by the combustion of the powder to a temperature above the critical temperature, say above 720 deg. C., and the great mass of metal back of this thin layer would suffice to extract the heat so as to cool the steel so rapidly through the critical range that *hardness* of the layer which had reached a temperature above the critical range would result.

"The steel so hardened would be brittle and without any plasticity, and the friction of the rushing projectile might easily produce a series of incipient cracks, which would in time develop in size and extent."

This theory seems to be that adopted by Bravetta. While not rejecting it totally, Crozier is not inclined to accept it, for he writes, "the evidence in favor of this view is not conclusive, and is rather against it than for it. There can be no doubt of the high temperature produced by the combustion of the powder," he continues, "but the velocity of the explosive wave is so great that there would be only a brief interval through which the heat might be communicated to the metal. To raise the metal to the required temperature would require a number of rounds of firing, and the body of the tube being considerably heated, the process would really be a hardening followed by a tempering process giving a fairly soft metal. The surface is, however, glass hard wherever it is found. Definite evidence in regard to the temperature of the metal in various parts of the tube is lacking, and until further evidence is obtained no satisfactory conclusion can be drawn.

"The second method by which hardness may be produced is by a process similar to wire-drawing and commonly referred to as 'cold work.'. . . In wire-drawing it becomes necessary frequently to anneal the metal in order to restore the plasticity and thus prevent it from cracking or breaking.

"According to Beilby, a surface skin may be built up by mechanical movement, which gives unmistakable evidence that the surface must have passed through a state in which it must have possessed the perfect mobility of a liquid. This surface possesses distinctive properties which differentiate it from the substance beneath it. Hardening thus results from the formation at all the internal surfaces of slip or shear of mobile layers similar to those produced on the surface by mechanical movement. These layers only retain their mobility for a brief period, and then solidify in a vitreous amorphous state, cementing together all of the surfaces of slip or sheer throughout the mass.

"Such a surface produced by polishing, burnishing, drawing, hammering, or cold work of any kind possesses the property of hardness and brittleness. This layer may be restored again to its natural state by annealing, which destroys the vitreous character of the layer and converts the metal again into its original crystalline, ductile state.

"By the application of this idea to the rifling of a gun we have a simple explanation of the hardening and cracking of the surface. By the passage of the rotating band of the projectile over the rifled surface, the surface of the steel is caused to flow in a mobile layer, and when solidification takes place it is in the vitreous or hard form. After the hard layer has passed a certain critical depth, the mobility is not longer transmitted through it when force is applied by the moving projectile, and the only alternative is for cracks to result from this force.

"The evidence seems almost conclusive that the hard layer and the cracks are produced by this process rather than by the heat alone. The microscopic evidence also favors this view. The hardened layer, etched with alcoholic nitric acid,

TRANSVERSE SECTION OF A CRACK IN THE RIFLING OF A 12-INCH GUN AFTER FIRING 239 ROUNDS, TAKEN AT 325.75 IN. FROM THE MUZZLE. POLISHED AND MAGNIFIED 100 TIMES TO SHOW THE STRUCTURE OF THE STEEL
From the Bureau of Ordnance, U. S. Army

is seen to be distinctly vitreous and not martensitic as would be the case were the layer produced by heating and quenching.

"This theory also accounts for the fact that in Section E, where there is undoubtedly the greatest amount of heat, there are the smallest number of cracks. At the higher temperature there is greater plasticity of the metal, and consequently there is greater opportunity for the cracks to fill up by flow of metal. The friction in this portion of the gun would necessarily be produced by the great rush of gases.

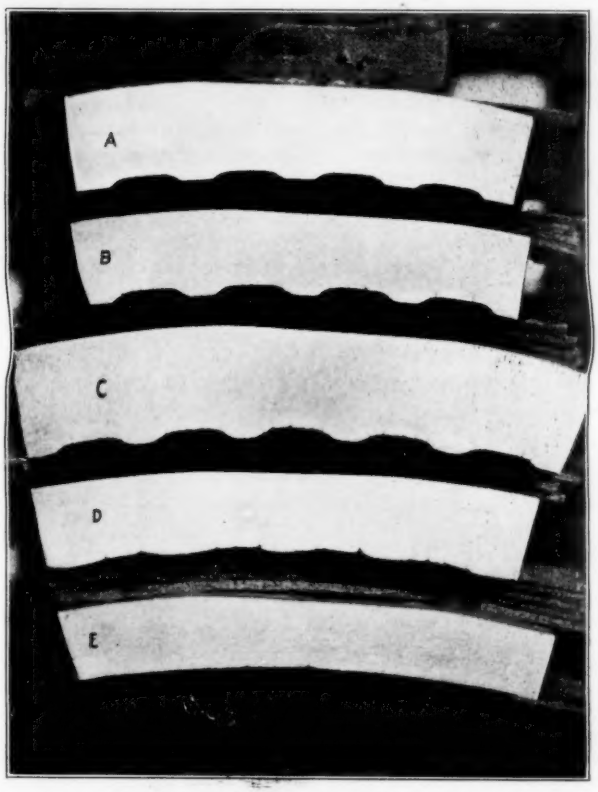
"The third method by which hardness may be produced is by increasing the amount of carbon on the surface of the metal. This might well be caused by a cementation process from the gases produced in the combustion of the powder. This would necessitate a very high percentage of carbon. Inasmuch as the hard layer is so thin and so difficult to do anything with, no direct evidence has been obtained. This method would best account for the fact that the hard layer is thickest in the firing chamber."

Gen. Crozier goes on to describe in detail a series of microscopic tests of various steels that had been subjected to erosion tests, to discuss the changes shown in their structure, and to point out their bearing upon the problem of erosion of big guns. He sums up the evidence in these words:

"It is believed by some that heat cracks are formed because of the formation of a hard surface layer due to heating of a skin of the rifled surface to a temperature above the critical temperature, followed by the sudden cooling of the layer by the large body of metal back of it. If this were true, then such a gun in which heat cracks have developed should show the martensite structure. In the examination of a considerable number of such steels no evidence of martensite has ever been found. In fact, troostite is never found. Therefore it is concluded that the development of heat cracks is due to the pressure of a hard surface produced by cementation of the metal by the products of combustion of the powder and by work put upon the surface by the moving projectile."

It is interesting to calculate how long the active life of a cannon endures, that is, how long it is actually at work. A British 305 naval gun's life, according to a calculation by Sir Robert Hadfield, is only three seconds! This figure is obtained, of course, by multiplying the average number of shots it can fire by the time a shot takes to pass through the tube. A 75 mm. gun, according to Bravetta, lives 25 seconds; a howitzer about a minute, an average mortar five minutes. Therefore the mortars are the Methuselahs of artillery.

"The record for brevity of life," he writes, "probably belongs to the 381 mm. gun with which the Germans in 1915 fired thirty shots on Dunkerque from a distance of 38,000 meters, and to the 'cannonissimo' that bombarded Paris from a distance of 120 kilometers. The projectile of the 381 mm. gun weighed 760 kilograms and had an initial velocity of 940 meters a second, but to hurl it the Germans had to use a charge of 315 kilograms of powder, which tried the metal to the limit of its resistance. This is why the cannon had such a brief life."



FIVE SECTIONS FROM A 12-IN. GUN AFTER FIRING 239 ROUNDS

A, at muzzle; B, 10 calibres from the muzzle; C, 20 calibres from the muzzle; D, forcing cone; E, beginning of rifling. (From the Bureau of Ordnance, U. S. Army.)

When the international artillerists come to the point of comparing their war-time notes with the recent experiments of the metallurgists and analyzing the eroded tubes of the steel veterans of the great conflict, they may possibly find an alloy of chromium, manganese, tungsten, copper, or some hitherto untried metal, that will be proof against the action of the high explosives now in use, and thus lengthen the life of the big guns that cost such enormous sums and are so soon dead.

CANS OF ALUMINUM INSTEAD OF TIN

The *Elektroindustrie* (Zurich) announces the discovery by K. Binggeli, of Bern, of a new aluminum solder which will make it possible to make cans for foodstuffs out of aluminum in place of tin. Rods joined with the solder have been tested by the Swiss National Testing Bureau and show a strength at the joints of 1,500 kg. per sq. cm. The electrical resistance at the joints is very low.

How Men Walk with Artificial Legs*

The Difference Between the Natural Gait and That of the Cripple

By Prof. Dr. R. du Bois-Reymond

HITHERTO judgment has been passed upon artificial legs partly by the general impression they produce with respect to lightness of weight and security of action, and partly by the testimony of cripples. However, observation with the naked eye is extremely ill adapted for the comprehension of the forms of such a movement as walking. For example, we need only recall the general surprise when the true positions of running horses were first shown by means of instantaneous photography. Great numbers of observers had endeavored to indicate the movements made by a galloping horse, but nobody succeeded in doing this until the proper means therefor was discovered in the art of photography. In the same way the gait of a human being has been incorrectly conceived and misrepresented by all observers who failed to make use of instantaneous photography.

For this reason the true nature of the act of walking with artificial legs can likewise be comprehended and measured only by the same means.

Modern photography affords an entire series of different experiments along this line. By far the most perfect of these is the photo-grammetric process for the study of the human gait made use of by the late Prof. Otto Fischer of Leipzig in his famous investigation in regard to this matter. However, this process is entirely too troublesome to be employed in ob-

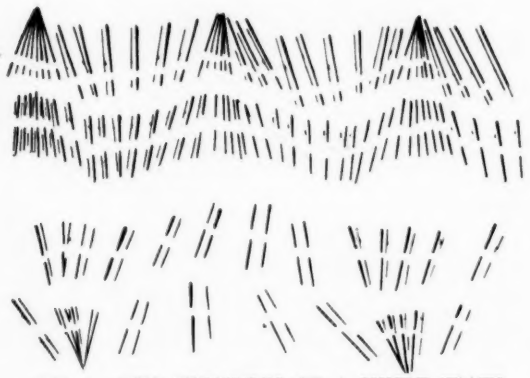


FIG. 1. TWO EXPOSURES ON A SINGLE PLATE

servations upon walking with artificial legs, since in this instance a very large number of different cases must be compared with each other. Furthermore, the high degree of precision obtaind by Fischer is quite unnecessary for our present purpose.

I have obtained the following data consequently by simplifying the Fischer process:

To begin with straight Geissler tubes are attached lengthwise to the legs of a man; through these tubes the induction current produces a flow of pulsating light, while the man moves in front of a camera in a darkened room. Upon the photographic plate only the tubes appear in such positions as they occupy during the flow of light. In this way we obtain, as it were, a series of motion pictures of a skeleton upon one and the same plate (Fig. 1). While it is true that such pictures do not permit very close measurements of the action, yet on the other hand they yield very clear and, in many respects, entirely trustworthy views of the processes of motion, from which many data can be obtained which it would be impossible to get by mere observation with the naked eye.

*Translated for the SCIENTIFIC AMERICAN MONTHLY from the *Zeitschrift des Vereines Deutscher Ingenieure* (Berlin), Aug. 4, 1917.

In the testing of artificial legs this process is of especial advantage since it permits us by making use of two cameras to show the movement of both legs at the same time (Fig. 2); we can then be certain that under the same conditions, *i. e.* with the same stride, the artificial leg and the sound leg have made the actual movement shown upon the plates.

Through the kindness of the Emil Busch firm in Rathenow

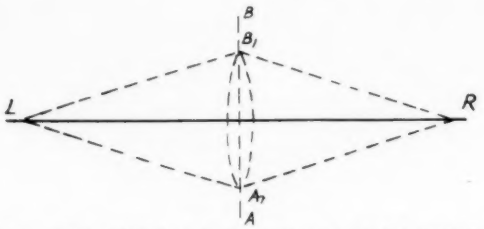


FIG. 2. TWO CAMERAS L, R, SET 5 M. FROM THE PATH A-B FOLLOWED BY THE PATIENT

two similar lenses of exceptionally high power were placed at my disposal for the purpose of taking double photographs of the walk of a man having an artificial leg. These experiments were conducted in the Physiological Institute of the University of Berlin. In order to be able to examine at the same time the large numbers of patients who had undergone amputation in the Reserve Hospital at G., I also applied to the firm of E. Zeiss in Jena, which likewise kindly lent me a pair of very beautiful lenses.

In order to understand the movement pictures of the walk with an artificial leg it was necessary, in the first place, to obtain a picture of the normal walk for purposes of comparison. It might be supposed that the Fischer view of the normal walk as shown in Fig. 3 would suffice for this purpose. However, it is not precisely adapted to our present object, since it represents a vigorous "walking" stride (length of stride about 0.8 m. or 2 6/10 feet, and rapidity 1.67 m./sk) whereas the wearer of an artificial leg takes much shorter and slower steps. To begin with, therefore, we must determine the form of the normal motions during a slow walk (Figs. 4 to 6), in order to compare with these the movements of the cripple provided with an artificial leg. Nothing further need be said here concerning this except to mention one basic observation, namely, that the upward and downward changes of place made by the center of gravity of the entire body are much smaller in extent during a slow walk than during a rapid walk.

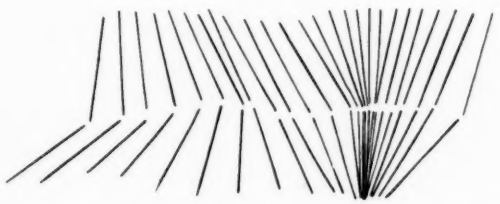


FIG. 3. NORMAL FAST WALK ACCORDING TO FISCHER

Thus far my observations have been confined almost exclusively to the movements of the upper and lower leg bones, from which, however, it is possible to comprehend the variations of place in a vertical plane of the buttocks. If we now compare the views of the walk of a man with an artificial leg with those of a normal walk equally slow, we perceive that

in all cases without exception the sound leg of the wearer of an artificial leg also deviates in its gait from the normal movement of walking (left half of Fig. 7 and Fig. 11).

It must be remembered also that a comparison between the movements of the artificial leg and those of the sound leg is by no means the same as the comparison between the gait of the artificial leg wearer and the gait of a normal man. As a matter of fact it must be differentiated in three respects: 1. The normal movement of walking in which both legs of a normal man move in the same manner; 2, the movement of the artificial leg; 3, the movement of the sound leg during the walk of a cripple wearing an artificial leg. In order, therefore, to comprehend and pass judgment upon the gait of artificial legs, it is necessary to compare views representing the sound side and the crippled side of the wearer with views of the normal gait, instead of merely comparing the sound side with the crippled side of the same subject.

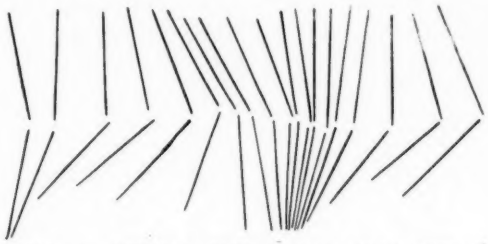


FIG. 4. NORMAL SLOW WALK (48.5M./MIN.)

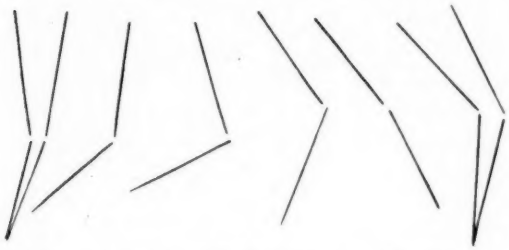


FIG. 5. NORMAL FAST WALK (141.6 M./MIN.)

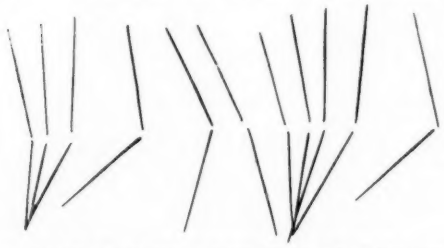


FIG. 6. SAME AS IN FIG. 4 DIVIDED INTO SAME NUMBER OF POSITIONS AS IN FIG. 5

I. *Comparison of the Views of the Cripple Side (Furnished With an Artificial Leg) With the Normal Movements of Walking.*

1. During the movement of swinging forward the artificial lower leg hangs back much less than the normal leg. In a slow normal walk the knee is accustomed to bend from 140° to 130° while the movement of the artificial leg is 20° to 30° less. Artificial legs of different construction vary perceptibly in this respect, as can be seen in Figs. 8, 11, etc.

2. While the artificial leg is resting upon the ground and supporting the body it remains fully extended, as shown in Fig. 8, etc. The knee of a normal leg on the contrary remains slightly bent during the act of support, as shown in Fig. 4.

These two characteristics are always present in the action of artificial legs. They can be readily traced to a mechanical cause. In the walk of a normal person (see Fig. 4), when the point of the foot has been lifted from the floor, the lower leg is drawn up for a moment and then swings freely, while the upper leg is drawn up for a moment and then swings while the upper leg is brought forward. Through the movement of the upper leg the upper end of the lower leg is carried forward with the former, while the lower end at first lags behind, which increases the flexion of the knee. When the upper leg comes forward again the lower leg follows it with increasing rapidity so that the flexion of the knee is decreased once more. Shortly before the foot is set down the forward movement of the upper leg either ceases or is retarded and since the under leg swings further freely the leg at once assumes the extended position.

In the case of an artificial leg it is obvious that the lower leg is not drawn up at the beginning of the swing, hence the flexion of the knee is produced exclusively by the lagging behind of the lower leg and is, therefore, weaker and slower. It must be remembered furthermore, that the common center of gravity for the lower leg and the foot in a natural leg is found at about the middle of the lower leg, whereas it is generally lower down in an artificial leg fitted with a boot.

The cause of the second difference between the motion of the artificial leg and that of the normal leg, namely, that the knee remains extended while the leg is supporting the body, consists merely in the fact that the artificial leg lacks the muscular tension necessary to enable it to act as a support while in a slightly flexed position.

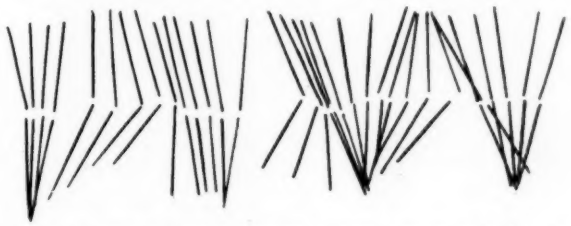


FIG. 7. SOUND AND ARTIFICIAL LEG AFTER FIRST DAY

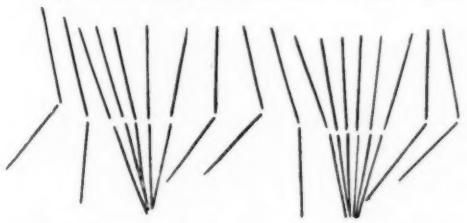


FIG. 8. SAME AS FIG. 7 AFTER FOUR WEEKS' USE

3. A third difference between the normal gait and that of the artificial leg is that the hip upon the side of the latter is lifted considerably higher during the swing of the artificial leg than is the case in normal walking, as can be seen in Figs. 8 to 11, etc.

Since at the beginning of the swing the artificial leg is incapable of being moved either at the knee or the ankle, like a natural leg, through musuclar activity, and hence swings with a slighter flexion, there is a tendency shown by the point of the foot to drag. This tendency can be avoided by lifting the hip higher. But the hip must also be lifted when the body is turned towards the other side as happens in normal walking. Furthermore, the wearer of an artificial leg lacks the ability to "push off" properly from the ground as is done at any rate in many kinds of walking, by a person with a normal leg. It is probable that the cripple compensates for this defect by a fling of the buttocks. In order to determine whether this supposition is correct I made views of the forward and backward movement of the buttocks of men equipped with artificial legs; these views showed first that in this point also the natural gait differs from that of the artificial leg, since in the latter case the inclination of the buttocks is considerably more marked. However, these variations still remain to be studied in more detail.

In any case it is evident that various conditions operate together in the matter of the increased lifting of the hip.

In some cases, especially in beginners, the hip and with it the whole body is quite obviously lifted powerfully upwards and inclined towards the side of the supporting foot in order to fling the artificial leg forward with the required impetus. This very unskilful movement is abandoned as the patient becomes increasingly accustomed to the artificial leg, but in most cases the marked lifting of the hip continues permanently (see Figs. 7 and 8).

The curve described by the hip presents a different outline in patients of different degrees of skill in the use of the artificial member. In some cases the apex is quickly reached (see Fig. 9) and the largest part of the curve begins at the concavity, while in other cases the apex of the curved line

FIG. 9. ARTIFICIAL LEG, LIFTING OF HIP

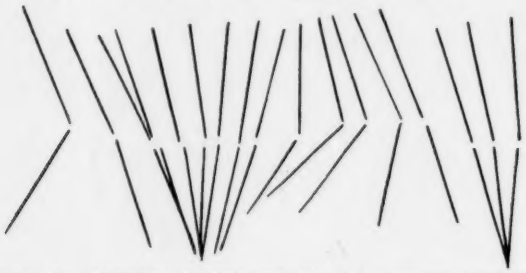


FIG. 10. ARTIFICIAL LEG, IRREGULAR LIFTING OF HIP

FIG. 11. APEX OF LIFT NEAR END OF CURVE

lies quite near the end (see Fig. 11) so that there is a steep decline at the end. Presumably the same object is here attained in two different ways. Furthermore, there are some cases in which the curved line or "wave" rises and falls quite regularly (see Fig. 8, etc.).

In connection with the excessive lifting of the hip, especially in those cases in which the apex of the curve occurs near the end of the swing, there is frequently found a fourth deviation from the normal in the motion of the artificial leg, consisting in the fact that before the setting down of the foot the leg is swung too far forward and then drawn back again. In the normal gait forward movements in space are made exclusively. It is true that there is a relative backward movement but this backward movement is never absolute. Each such movement indicates likewise unnecessary double work. The unskilled wearer of an artificial leg, on the other hand, not infrequently makes backward movements either with the artificial leg or with the sound leg. These movements are generally quite plainly indicated in the accompanying illustrations by the circumtsance of two adjacent lines crossing each other (Figs. 7, 16, etc.). Such a crossing of the lines takes place when the upper leg before the end of the swing of the leg is brought back with more force than in the normal gait, in order to fling the lower leg forward. Crossings of the lines appear in the views of the lower leg when before the setting down of the foot the leg is thrown too far forward and must be drawn backward and down in order to touch the ground.

II. *Comparison of the Movement of the Sound Side of a Cripple With the Gait of a Normal Man.*

The only deviation from the normal which is visible in all the views of the movement of the sound side of a cripple wearing an artificial leg consists in the increased lifting of the hip during the swing. Practically the same thing can be

FIG. 12. SOUND LEG OF SAME AS SHOWN IN FIG. 11

FIG. 13. SPECIMEN OF SKILLED USE OF ARTIFICIAL LEG

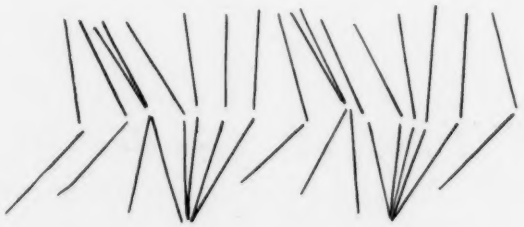


FIG. 14. SKILLED USE OF ARTIFICIAL LEG

said of this as in the case of the lifting of the hip on the side furnished with the artificial leg. (Fig. 12).

Besides this we also observe in some cases the crossed lines upon the sound side, which indicate a backward movement of the leg in space (Fig. 21). The upper leg especially is frequently moved forward too much at the end of the swing and must consequently be drawn back again. Especial attention may be called to the fact that a practised wearer of an artificial leg tried three different artificial legs of various manufacture in succession and in each case made the same mistake with the sound leg. (Figs. 13 to 20).

This observation is of peculiar importance since it proves that such a mistake upon the part of the wearer of an artificial leg may have a physiological cause instead of a merely mechanical one. We can obviously explain in this way the fact that the patient in his efforts to control the artificial leg with which he is unfamiliar makes movements of excessive extent with his stump. Because of the mutual relation which the nerve centers governing the motion of the legs bear to each other, this effort involuntarily occasions excessive action of

the sound leg. This teaches us that a patient who is learning to make use of an artificial limb must not only learn to make the correct motion with the stump, but that the sound leg must be trained also to prevent it from making all sorts of unsuitable movements through its nervous coördination with the stomach (Fig. 21).

While at first glance the deviations from the normal described above may not seem very essential, careful consideration shows that they exert quite an important influence upon the degree of effort required by the act of walking. According to Fischer in a normal fast walk the hip is raised and lowered about 4 cm. at each stride and the center of gravity of the whole rises and falls a like distance. According to Katzenstein and

FIG. 15. SPECIMEN WITH DIFFERENT TYPE OF LEG

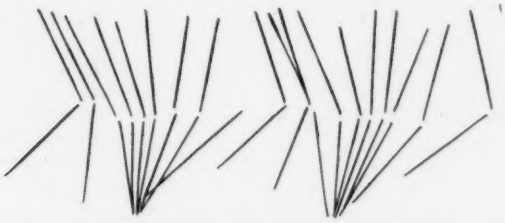
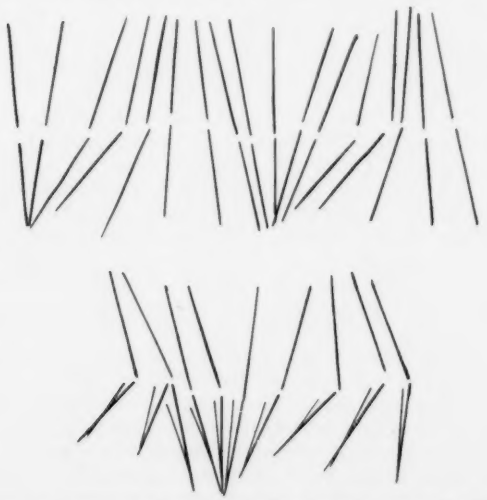


FIG. 16. SPECIMEN WITH DIFFERENT TYPE OF LEG

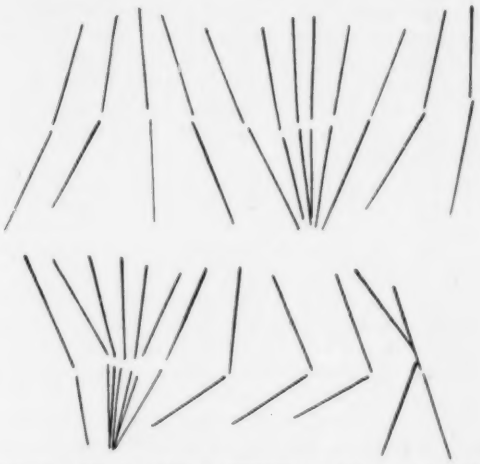


FIGS. 17 AND 18. NOTE THAT THE SOUND LEG MAKES A BACKWARD MOVEMENT

Zuntz the total work done in walking by a man weighing 55.5 kg. (about 122 pounds) is 315.4 mkg. Counting eighty steps to the minute the lifting of the center of gravity alone would equal 80 x 0.04 x 55.5 = 177.6 mkg., *i. e.* something more than half of the total amount of work done. When, therefore, the lifting of the hip and with it the lifting of the center of gravity is increased to double the normal, which not seldom occurs in the wearing of an artificial leg, the work done by such lifting amounts to 355.2 mkg. per minute; thus we see that such lifting movements alone require a greater expenditure of energy than the entire action in a normal walk. Accordingly, when all other conditions remain the same the increase of the lifting movement increases the work done in normal walking by 164 vH. These facts show the necessity of making use, in the examination of artificial legs, of a process that will reveal even very slight differences in the movements.

SUMMARY.

In the testing of artificial legs it is not only useful but almost indispensable to record and study the movements of walking by means of instantaneous photography. By far the most exact process devised for this purpose is that of Otto Fischer. Since, however, this process is much too troublesome to be applied in the comparison of a very large number of cases, we must content ourselves with the somewhat lesser degree of precision which is obtained by combining the older process of Marey with that of Fischer, as follows: The longitudinal axis of the members is made recognizable by attaching to the members a Geissler tube through which a succession of induction flashes is sent at brief and equal intervals of time. The movements are made in a darkened room with a



FIGS. 19 AND 20. SAME ARTIFICIAL LEG AS IN FIGS. 13 AND 14

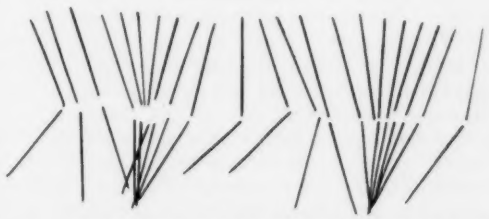


FIG. 21. SOUND SIDE, STANDING STILL DURING ACT OF SUPPORTING THE BODY

continuously acting camera, so that the tubes make an impression upon the plate, so to speak, as of the movements of a skeleton in the same series of positions which they had at each passing of the flash. The resulting views show plainly that the movement of the artificial leg always differs from that of a normal leg in certain particulars, and also that the movement of the sound leg of a cripple likewise differs from the normal gait.

That these deviations though slight are not unimportant, is shown by a simple arithmetical calculation proving that merely through the increased rise and fall of the body at each step taken the amount of work done in walking with an artificial leg is increased by more than fifty vH as compared to the normal.

This calculation shows the necessity of examining the action of artificial legs by means of a process which will show the slighter differences as well as the greater ones in the form of the movement.

A Prime Cause of Inefficiency in Industrial Organizations*

Determining the Best Way to Do Work

By Frank B. Gilbreth, Mem. A. S. M. E. and L. M. Gilbreth, Ph.D.

ALL trades, and particularly those connected with this Association are unnecessarily inefficient to-day. You know it; we know it. What are the causes?

There are demands for changes in wages, for better hours, and for increased production. Are these demands just or unjust? In any case the demands must be answered in some way.

The answer lies in the increase of skill. In our paper presented to this Association last year, we showed you how skill could be discovered, measured, standardized, and transferred, and we brought as illustrations many films that showed in great detail the various stages of the process.

The problem facing us as a nation, and you as a group of metal working men, last year was largely a problem of maximum production. Some phases of the labor problem were not so pressing at that time, because of patriotism inspired by war necessities. To-day the labor problem stands in the foreground of attention. We are making you the same answer to-day—increase of skill, and that alone can answer the present demands upon you.

It can scarcely be necessary to demonstrate to you that lack of skill is the prime cause for inefficiency in your particular work, as it is in all kinds of work—in this country, and in fact, all countries. You may not, however, as yet realize that lack of proper teaching is the underlying cause of this lack of skill.

Efficiency in teaching consists primarily of three things: *first, determining the best way to do work;* second, *conveying in least time, information of how to do work in the one best way;* third, *presenting information so that it can be longest remembered.*

The greatest obstacle to overcome in increasing skill of a group of workers is that they have been taught the average methods by the average teacher. We are all ready to admit this. We are not all, however, as ready to admit that the average teacher has had no opportunity to learn the best method, and is not equipped with modern devices for conveying information. The fault lies ultimately, then, with the industry itself, in not having determined, captured, and recorded the one best way, or at least the one best way extant, and put it at the disposal of the teachers.

The first step in this process must consist of recording the best present practice. This is, however, not so simple a process as it might seem to be. The records must include many things. Our researches have emphasized several laws, and an idea of these is essential if the existing information on this subject is to be secured, and this *must* be secured before the one best way can be deduced.

For example, it is a law in motion study efficiency that no two workers are found to use precisely the same motions, even in the same kind of work. This necessitates observing and recording the activities of *several*, and oftentimes of *many* workers performing the identical operation. If you are observant, you have noted this in your own work.

It is a law of Motion Study efficiency that every demonstrator has been found to have at least three sets of motions, and that he *does not* and *can not* use the same motions when he is working with the automaticity of skill at the usual speed that he uses when he demonstrates his methods at the slower, "demonstration-speed." This necessitates making records of usual and demonstration methods, and also at reduced and increased speeds, in order to note and record the variations.

It is a law of Motion Study efficiency that the synthesis of the best portions of the methods of two or more of the best workers will be found to present a method that is more efficient than the best method of any one worker. In the film shown here you will note that the methods of the workers vary exceedingly, and that some of the so-called "best workers" use some very inefficient methods, such as not using the left hand properly.

It is a law of Motion Study efficiency that the worker with the best record of outputs is not always found to be the best for demonstrating personally the one best way to the learner. His large outputs may be the result of his superior strenuosity and in spite of a poor method. Furthermore, knowledge of pedagogy does not necessarily accompany knowledge of one's job. It is necessary, therefore, to demonstrate the various methods to the best available teacher, and to record his method of demonstrating the activities of a learner.

The best way is then determined by making records of the usual and demonstration methods of the best workers available, by analyzing them, and combining the best elements of the methods into the one best method, and by having this demonstrated by the best available teacher.

Having then secured this record, the actual teaching process consists of using the resulting film as a teacher, supplemented by the usual available teaching methods, oral, written, or whatever they may be. This record of the one best way having once been obtained is available forever. It teaches all new-comers the best that has been. It will present the information in the best way that the best teacher has ever presented it. This in no way resembles the so-called "commercial moving pictures" that you have so often seen. This information, "available forever," is also *instantly* available. It can easily be brought to the foremen's meeting. It can be duplicated easily and cheaply and put at the disposal of manual training schools and corporation schools.

Compare this with the way you are now teaching trades. In 1910 we said in Motion Study: "The present apprenticeship system is pitiful and criminal from the apprentice's standpoint, ridiculous from a modern system standpoint, and there is no word that describes its wastefulness from an economic standpoint." The great Amar has said the same obtains to-day in his country. Your present methods of teaching must be overhauled and research laboratories inaugurated.

Every day that passes serves to emphasize more strongly the correctness of these methods which are based upon teaching through the eye. Written instructions, charts, drawings, lantern slides, stereographs, and moving pictures—these all serve as teaching devices for visualizing the process. Micromotion films have proved themselves particularly adapted to an efficient learning process. The activities to be studied may be repeated, at will, as often as may be desired, according to the needs of the learner. An activity may be analyzed into its component parts, and even into the elements of the motion by taking a large number of pictures per second and then slowing down the process when the film is exhibited at the usual rate of speed. Again, the activities may be analyzed by means of mechanical and other drawings made especially to illustrate one point at a time, with all extraneous subjects omitted. An activity may be summarized, by taking the pictures at much slower rate of speed than is usual, and then exhibiting them at the usual speed.

"*Attention*" may be secured and interest held by *exaggeration* as to scale and by means of the "surprise" by sudden changes of scale and also by the use of the "close-up." *Emphasis* may be secured by means of moving cartoons to illustrate a particular point. The *sequence* of operations may be made impressive by running certain portions and in certain cases, all

*Presented at the Convention of the American Foundrymen's Association, Philadelphia, Pa.

captions inserted in the picture, which allows of including "reasons" with "directions."

"*Continuity of thought* can be obtained by associating each point or picture to be remembered with the point that comes immediately before it and immediately follows it through moving mechanical drawings or cartoons.

Likenesses to other activities can be demonstrated by including bits of film showing similar activities in other lines of work. These are only a few of the benefits of the film as a teaching device, pointed out here that you may note them as exemplified in the film itself. Note especially the possibilities for associating the various steps of an efficient learning process, because upon a proper association depend quick learning, easy remembrance, and efficient activity. The memory experts base their systems upon such association. They, however, have been obliged to be content with "mental pictures," made by a "mental process," without the actual pictures having been previously recorded through the eye, while we have here a device which makes such recording through the eye possible and simple, and the resulting remembered image vividly and easily recalled.

It may seem a long cry to an increased production of cores from a motion picture film of core-making—but some day you must come to realize that, through the discovery and adoption of "the one best way to do work," and through that alone can come the increased production, the increased wages, and the increased health and happiness of workers that are essential. In the meantime, we can do nothing but come before you year after year to present the methods of recording and teaching this best way, and to advocate such recording and teaching as a remedy for the evils which you acknowledge beset you.

As for the practicability of the method, in order to cooperate in work for the blinded, to make available to a group of men and women who desire factory work a new activity, and to relieve sighted workers of work which might be done by the blinded, thus leaving the sighted free for work requiring eyes, we have, during the past year, through the co-operation of Mr. A. B. Segur and the others of the Red Cross Institute of the Blind, made records of one of your own activities, namely, core-making. As a result of these records, and the deduction of the one best way for making cores, Professor Wallace, Director of the Red Cross Institute of the Blind, at Evergreen, Md., has just sent to us an announcement of their courses, including a course in core-making. We are to-day presenting some of these films to you. They will show you that this process applied to one small division of the work of an industry, will standardize the activity involved, will make possible its division into parts requiring different capabilities, will add a new group of available workers, will supply a new element of interest, will result in increased production, will make possible the pay of higher wages, will eliminate unnecessary fatigue, will exemplify efficient motions, and will do away with a prime cause of inefficiency by supplying an adequate means of discovering, standardizing, and transferring skill.

The method recommended by this paper has been criticized by some who have based their judgments upon their experience limited to the so-called commercial moving pictures.

It has sometimes been thought that the expense of this method is so great that it could be afforded only by groups of employers or by an association. But this is not true.

It is not expected that this method is ever to be carried so far as to approach a diminishing return, and when it is realized that the difference between usual and customary output and the outputs resulting from this method of research and teaching is usually more than three to one and sometimes five to one, the importance of recording the one best method of doing work and teaching it can be realized.

Men of the metal industries, you must recognize that this is a crucial moment in the industrial development of this country, that the time for petty disputes, for trade secrets, for "minor wastes," for retrogression or lack of progress is past. You have shown your interest in this subject by inviting us to present to you for the second time films showing this particular method of attack. You have welcomed illustrations from your own particular field, as supplementing those from the other fields in which you were interested. It remains now for you, yourselves, to attack your own industry; to eliminate the inefficiencies there existing; and if you will, to serve as a model to other industries by co-operation both in research, in interdissemination, and in installation. Such co-operation is becoming more general everywhere. It is indicated in the new book by the Bloomfields on Employment Management. It is shown in Mr. Gantt's new book on "Organizing for Work," where he emphasizes the importance of visualization by means of charts. Any method of co-operation is commendable. The need for this particular type of co-operation at this time is that the "during the war" desires and methods of attaining efficiency for patriotic reasons are lapsing with the much-desired days of peace. In your industry, you evolved magnificent results and efficient methods at the call of your country. It is your duty now to see that these do not now lapse and perhaps disappear through the pressure of other problems. Maintain, then, your before-and-during-the-war co-operation by combining to record your best methods, and to put these together with the one best way of research at the disposal of your entire industry. It is the greatest offering that you can contribute towards meeting the economic needs of to-day.

RELATION BETWEEN WEIGHT AND SEX IN EGGS.

THE claim is made in a paper recently read before the French Academy of Sciences that the weight of eggs bears a definite relation to the sex, provided the breed be homogeneous and pure and the hens laying the eggs of approximately the same age and size. This theory is advanced by M. Leinhart, whose attention was attracted to the matter by the obervation that in all breeds of fowls the cock is always larger and heavier than the pullet of the same age. By numerous experiments he found that the variation in weight for the breeds examined was between 500 grams and 1 kilogram or more in the adult fowl. Furthermore this difference appears even in young chicks, varying from 18 to 27 gr. in those five days old. The idea naturally suggested itself that the same difference might exist in the egg. In the spring of 1918 M. Leinhart selected sixty eggs chosen because of their size from a lot of 350 all laid by Leghorn hens. These 60 eggs varied between 59 gr. and 70 gr. in weight. Repeated experiments previously had shown that the average weight of Leghorn eggs is 62 gr., the minimum weight being 54 gr. and the maximum weight 70 gr. Eggs weighing less than 58 gr. or more than 66 gr. are rare, however. Among the eggs chosen 7 weighed slightly less than the average while the others exceeded it. The 60 eggs were hatched in an incubator and yielded 48 chicks, comprising 37 males and 11 females, *i.e.*, a proportion of 77 per cent. of males. This result convinced the experimenter that the sex of fowls can be determined in the egg, a fact whose knowledge would naturally be of great advantage to breeders. Mr. Leinhart expects to continue his experiments but warns breeders or scientists who would do likewise that the fowls experimented with must be pure bred, that the hens be of the same age and that the eggs be gathered when the laying period is at its maximum. This is important since year old pullets lay eggs which are considerably smaller and less in weight than the normal average of the breed, while during the course of a year the eggs of the same hen, even when fully adult, are considerably smaller at the beginning and at the end of the egg-laying period than when it is at its height. Hybrids cannot be employed for the experiment, since here the Mendelian law comes into play and the eggs produced vary greatly in size correspondingly.—M. Tevis.

A 75 HORSE-POWER TRACTOR HAULING 13,400 FEET OF GREEN YELLOW-PINE LOGS

Logging with Belt Tread Tractors*

The Use of "Caterpillar" Trailers

By C. D. Metcalf

DURING the war one of the much criticized lumber corporations promoted one innovation in logging methods which is destined to have a far-reaching effect on the logging industry. With the sanction of the Production Board, this company purchased two 45 horse-power belt-tread tractors with the intention of using the engines for hauling logs on trailers over newly made roads. It was soon discovered that the tractors could be profitably employed for skidding as well as for hauling logs on wagons. The tractors were put into commission for skidding and were operated with much success.

However, it remained for T. P. Jones, who is accredited with having introduced many novel ideas in logging engineering, to seize the real possibilities of the belt-tread tractor for skidding. Working with the manufacturers of the tractors, Mr. Jones has perfected a belt-tread tractor and trailer system, under which logs may be put in for approximately one-half the expense of working teams, as commonly practiced in Idaho.

In lieu of the round wheel trailers, the company is now using for skidding, the so-called "Caterpillar Bummer." This consists of a truck with a single bunk, (or sometimes two bunks) mounted on tracks built up much on the style of the tractor tracks. The bummer construction is shorter than the tractor, the weight of the load being supported by three truck wheels on either side.

The bummer and its load are pulled by a 45 horse-power tractor of the model made famous during the war for artillery hauling purposes. It has a very long and flexible track, which conforms to, and gives traction on uneven road surfaces. There is no front steering wheel. The steering is accomplished by means of two clutches, each of which controls independently its side of the belt tread. No equalizing or differential gearing is used. The entire power of the tractor motor may be employed on either track when occasion requires. Each track has independent brakes. Thus the operator may apply the brake on one truck, and by engaging the friction clutch on the opposite side can turn the tractor in its own length. The motor is of the four cylinder, slow speed, heavy duty type with flyball throttling governor. The traveling speeds (1½ to 4 miles per hour) are obtained by gear changes. This engine will pull its load over logging roads too soft and rough to be easily negotiated with teams or motor trucks. The great ground bearing surface of tractor and bummer prevent the outfit from miring down.

The first outfit purchased was used in "selective" logging operations, but later, as the utility of the system was proved, the company installed a second outfit, and is now putting in the major part of its logs with this equipment. The tractor and bummer are used regularly for skidding on hauls up to a mile. Briefly, the plan is to cut a road from the railroad through the timber for the desired distance. The trees are felled across the road and for a short distance on either side. The logs are trimmed and several of them (depending upon the size) are raised on one end until supported by the bummer; the other ends skid on the ground. Twenty-five hundred to 3,000 feet is the usual bummer load.

The two outfits have been operated at Bovill, Idaho, for a year, having been put into service in the fall of 1918. They proved highly efficient in the winter for skidding operations on snow and ice roads.

TEN-TON ARTILLERY TRACTOR HAULING 6,000 FEET OF WESTERN PINE ON AN EIGHT-WHEEL TRAILER

*From the *West Coast Lumberman.*

In the skidding operations with 32-foot white pine, two outfits are averaging 40,000 feet per day on one-half to three-quarter mile hauls. Nine men will average 20,000 feet per

TRACTOR OPERATING WITH SLED TRAILERS IN THE SNOW

day, or 2,220 feet per man per day. This is for skidding logs in three lengths within a half-mile radius.

The belt tread tractor with trailers may be profitably used at some camps in lieu of a railroad. The expense of the equipment is trifling as compared with the cost of a railroad, and when the job is finished the outfit can be quickly moved to another haul. Wherever a spur of railroad is thrown in it has to stay when you leave, for you don't take up ties and you cannot remove your road bed. This engine will build the road over which it is later to travel. It is the best road builder in existence.

A 45-HORSE-POWER BELT-TREAD TRACTOR SKIDDING WITH A "GO-DEVIL"

It will pull stumps up to 18 inches in diameter in direct pull without the use of tackle, or it will pull 20 feet of engine graders or train of dirt wagons. It is a complete road building power plant provided with its own steel road bed. Where the proposition is strictly one of hauling over a considerable distance, say from two to five miles, it is essential to load as heavily as possible and to keep the engine constantly on the road. On these long hauls it must be borne in mind that the tractor outfit is really doing the work of a steam railroad, and the results will depend largely on the condition of the road bed.

The better the road is kept up the bigger the loads and the smaller the expense. A good practice is to attach to the rear trailer of a "Caterpillar" logging train a "V" drag which follows the wagons and smooths out the rough spots in the road. An occasional trip with this drag will keep the road in fine condition. Where the roads are very dusty a sprinkler wagon may be made a part of the equipment.

On these long hauls where round wheel trailers are used, the tires should be very wide; 10, 12 or even 16-inch tires are none too wide. Some loggers recommend the 3-wheel trucks commonly used in Louisiana. If the roads are very soft or sandy the belt tread bummer is better than any of the wheel trailers. These trailers will carry their loads wherever a belt tread tractor will go. The wagons should be of sufficient capacity to handle 3,500 feet of green yellow pine logs. Three wagons with 3,500 feet each, or 10,500 feet makes a good average load for a 75 horsepower tractor.

This large tractor is primarily a "roader." It is almost twice as big as the 45 horsepower tractor previously described, but embodies the same features of construction, except that it is equipped with a front wheel. The front wheel is necessary to give the big tractor balance. On the 45 horsepower tractor the front wheel is dispensed with; on this account the smaller model is to be preferred as a "yarder."

B. F. Pierce, manager of a lumber company at Colville, Washington, describes his operations with 75 horsepower tractor hauling equipment as follows:

"The tractor moves at the rate of 2¼ miles per hour under load, drawing three 3-wheel trailers, which weigh 7,800 pounds each and are equipped with 16-inch tires. The usual load of logs transported is 11,000 feet. On a three-mile haul we make three round trips daily, bringing in an average of 30,000 to 36,000 feet per day. Estimating about 8 pounds per foot as the weight of green western pine logs the combined weight of the load, including trailers, totals 111,400 pounds. It will be remembered that this tractor loads directly in the woods under any sort of condition. It requires only two men to operate the outfit. We figure that the tractor displaces ten teams. The average price now being paid for a team and driver is $9.00 per day. This is our second season with the tractor and we are pleased with its performance. The old horse team is a thing of the past with us. Using distillate at 17 cents per gallon, and allowing depreciation sufficient to make the life of the outfit five years and operating with two men we figure the cost of a tractor outfit at $30.00 per day. Thirty dollars would not pay the expense of the teamsters to drive the horses the tractor replaces."

The company uses nine trailers; three are kept constantly on the road; three at one end of the haul are being loaded, while three at the other end are being unloaded. Up to date, and after two season's use, they have practically no expense for repairs and no delays, and they state that the tractors are as good as new.

For winter work in Eastern Washington, Idaho and Montana, heavy logging sleds take the place of the trailers. Under favorable conditions it is possible for a belt tread tractor to haul 20,000 feet or more per trip loaded on sleds. The tractor tracks gain easy footing on snow roads, and where necessary, as on

"BUMMER" USED AS TRAILER IN CONNECTION WITH THE BELT-TREAD TRACTOR

ice roads, the tracks may be fittted with angle steel grousers bolted to the shoes. This gives the engine a firm bite on any road bed.

For loading operations the tractor may be equipped with a spool or windlass attachment. This consists of a cast iron drum which takes the place of the stationary pulley attachment on the smaller model, or is placed on the rear countershaft of the larger tractor. The engine can thus be made to do the work of another team and driver.

Operators are plentiful. Thousands of young men who enlisted in the "Tanks" have returned from France where they gained much practical experience in the handling of tractors. Many of these men had tractor experience before they entered the service and were selected for the tanks on this account. Now they can qualify as experienced tractor operators. These men have been used to hard knocks and accustomed to discipline. Furthermore, and most important, they are not of the Bolshevist element. The average tractor logging outfit is doing the work of ten teams with ten drivers; and many plants will welcome the system as a means of relief from the high cost of horse feed and the I. W. W.

The belt tread tractor with its powerful motor and crawling ability can be put almost anywhere. On the west front the engines crawled in and out of shell holes and pulled their loads over battle-torn roads and made good. The tractor can do all these things in the woods.

At every camp there is more or less extremely rough yarding to be done. Here the tractor is called upon to repeat its war-time performances. The writer recently witnessed the operation of a tractor known as a "10-ton artillery model" at a camp near Dover, Idaho. This big tractor is built narrower and with much greater clearance than the models previously described. It has a steel track made up of one piece links and is very long and flexible. There are six truck wheels on each side. It is driven with a 55 h. p. heavy duty motor.

This tractor would dash into the timber, climbing over stumps or crawling over low spots in the soft earth. The steel tracks would drape over a log like a rope. Then the machine would spin around a standing pine, grab a 1,500-foot log and snake it back to the road almost as quickly as we can tell the story. The ease with which this engine negotiated rough going was remarkable. It is easy to understand the respect with which Ludendorff's men regarded the tanks. For the belt tread tractor is the tank converted to uses of peace.

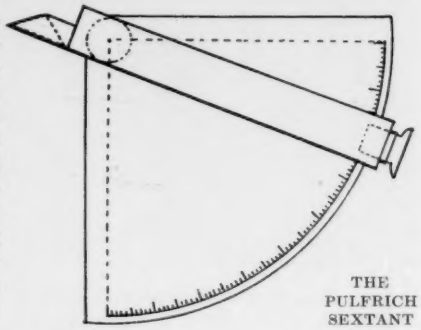
THE PULFRICH SEXTANT.

F. J. B. CORDEIRO.

HITHERTO observational navigation has been impossible at night. With the coming of darkness, the horizon vanishes and with it all possibility of taking an altitude. On land, artificial horizons consisting of surface of quicksilver, molasses, etc., are substituted, but at sea those are impossible. A horizonless sextant has long been a great desideratum and attempts have been made to obtain the necessary level surface from which to measure an altitude by attaching a spirit level to an ordinary sextant, but the success has been meagre. The reflected image of the observed object is brought into line with the bubble and the observer tries to estimate when the centre of the moving bubble coincides with the object.

Many years ago, I was shown such a "bubble" sextant by a nautical instrument maker in San Francisco. He told me that he rarely sold one and that they were of use only in certain cases where a result having a wide margin of unknown error was better than having no measurement at all.

Several years ago the first horizonless sextant which could lay any claim to accuracy, was constructed by Dr. Carl Pulfrich, head of the department of instruments of precision, (Mess-Abteilung), of the Carl Zeiss works of Jena, Germany. Dr. Pulfrich represents a type hitherto rare outside of Germany, viz., a man of high scientific attainments engaged in commercialized science. Had it not been for his patient and ingenious experimentation, it is doubtful if we should have had such an instrument for many years. When he has once decided that an idea is feasible and desirable, there are few men abler to put it into practical form, as is evidenced by the many valuable instruments he has produced.



THE PULFRICH SEXTANT

The figure represents the instrument diagrammatically. It is essentially a sector carrying an arm which supports a small telescope. In front of the objective is an isosceles reflecting prism, rigidly attached, its base being parallel to the axis of the telescope. The sector which is graduated, and the arm which moves over it, are pivoted at the center of the arc, and the whole is supported on a handle behind the sector (not shown) as in an ordinary sextant. The pivot is supplied with ball bearings and has practically no friction.

The arm with its appurtenances, clamping screw, vernier, shade glasses, etc., which are not shown, is accurately balanced about the pivot, so that the instrument, which is weighted, always hangs in precisely the same position. There is a spring (not shown), worked by the pressure of a finger, which clamps the sector so that it cannot oscillate, and at the same time removes all pressure from the ball bearings. The graduations, for equal arc, are twice as many as in the ordinary instrument, for here a quadrant is a quadrant and not an octant. The prism serves as a collimator. The rays of a star pass partly through the prism and partly through clear air, so that it is possible by adjusting the area blocked by the prism to have the direct and reflected images of equal brightness.

As the instrument pendulates, the direct image moves one way and the reflected image the other way, but twice as far. By a touch of the finger, it is easily possible to bring the pendulation to a stop momentarily, and this momentary coincidence of the two images gives us our measurement. Even with a slight movement, it is easy to judge when the excursions of the reflected image, above and below the direct image, are equal, and this gives us our point. There is no such thing as "Dip" to be corrected for, and there are conditions of the atmosphere, resulting in an abnormal refraction of the horizon line, when the readings by this instrument will be more accurate than by the ordinary sextant. The radius of the sector is about 4 inches and the instrument weighs under a pound.

I visited the Zeiss works in 1908 and again in 1911. During the latter visit, I was easily able to confirm what Dr. Pulfrich had previously told me, viz., that it was possible with this instrument to measure an altitude accurately to one minute of arc. This is all that is required for accurate navigation. The manipulation of the instrument is as easily acquired as that of an ordinary sextant.

The present interest in the instrument lies in the fact that we are now entering upon an era when trans-ocean voyages in airships will undoubtedly become matters of routine, and navigation will have to be done with Pulfrich sextants. Certain portions of the ocean are habitually covered with low-lying fogs, but the airship sails over these and for the greater part of the time, both day and night, sights will be obtainable.

The instrument will be a boon to explorers enabling them to lighten their impedimenta by dispensing with heavy flasks of mercury troughs, etc., hitherto necessary for artificial horizons.

Scale Effects in Relation to Aerodynamics*

Testing Aeroplane Parts in Wind Tunnels

By H. Levy, M.A., D.Sc., F.R.S.E.

IN all branches of engineering design the question of scale effect is one of vital consequence. With almost the sole exception of those cases where the mathematical theory of elastic structures has enabled us to design the full-sized construction from a direct calculation of the forces and stresses that will be brought to play upon it, experimental investigations on models are the only means to hand for supplying the data upon which the full-scale design is to be based. Before such an investigation can be considered admissible however, the basis of prediction from the model to the full scale must be laid secure.

In no branch of engineering is this question of more vital consequence than in the new science of aeronautics. Full-scale experimental work in this subject, invaluable as it has been, particularly during the recent war, can never in the nature of things undertake the fine and delicate tests on all the numerous details and refinements that mean so much in the design and construction of a machine in which every inch of improvement is worth fighting for.

Full-scale scientific investigations on airplanes in actual flight suffer from the two inherent disabilities which in all first-class research one seeks to eliminate—(a) the temperamental defects of the pilot and (b) inadequate knowledge and utter lack of control over the atmospheric conditions.

If it be realized that an up-current of as little as 1 per cent may involve an error in the drag measurement of the wings of as much as 15 per cent., it becomes at once evident that only by an immense series of checking and rechecking by numerous test flights could full-scale research under actual flying conditions serve alone as a basis for design. Experimental means, moreover, for direct measurement of the forces brought into play during flight are not likely for some considerable time to be so far developed as to allow of a determination of the isolated effects of the small variations in design which together in the end sum up to considerable importance. The advantage that experiments on models in the wind tunnels possess over those on the full scale and in the open becomes at once apparent. Complete control can be exercised over the experimental conditions both as regards wind speed and the isolation of the effects on resistance and consequently on performance due to slight modifications in design. But these advantages are only to be had at—in many cases—the expense of facing an extremely serious difficulty—viz., the problem of scale, and it is with this aspect of the question that the present article is primarily concerned.

The construction by means of which the forces on the models are measured is shown in Fig. 1. It consists essentially of two rectangular horizontal wooden tunnels connected by a slightly tapered portion containing the propellor. When the latter is in operation the air is sucked in through the inlet and along the front or working portion of the channel. At the inlet mouth is situated a honeycomb to steady the flow and distribute the air uniformly along the channel.

Almost midway along the working portion, where the distribution in velocity across the section is most uniform, is placed the model fixed to a vertical support through the floor of the channel, forming a portion of the balance by means of which the forces and moments exerted on the model are measured. The air then passes through a second honeycomb, through the propellor and is discharged into the outflow distributor. The walls of the latter are composed of vertical laths spaced progressively to allow as far as possible of the passage of the slip stream air back into the room without the production of excessive turbulence by splashing against the wall.

Looked at in plan, the flow of the air in the room is as indicated in Fig. 2, and by such a symmetrical system the streaming in the tunnel proper can be maintained at a high degree of steadiness and uniformity. It is not until a distance of 1 in. from the wall is reached that any appreciable drop in the velocity is found. The wind speed in the channel is regulated by adjusting the revolutionary speed of the propeller in the usual fashion. In utilizing the wind tunnel for aerodynamic research two different classes of measurement are essential: First, the accurate measurement of wind speed, and, secondly, the measurement of the forces brought into play. The instrument upon which the measurement of wind speed depends is known as the Pitot tube. The general outline is shown in Fig. 3. It is composed of two hollow tubes fitting one inside the other and closed along the circular edge *AB*. The outer tube is perforated at the points *CDE* —and open again to the outside at *F*. The inner tube is open both at the front *AB* and at the end *G*. The fore part *LM* is placed parallel to the wind *V* whose speed it is required to measure. A tube of this nature moved on the end of a whirling arm is found by experiment to acquire in the inner tube,

*From *Automotive Industries*.

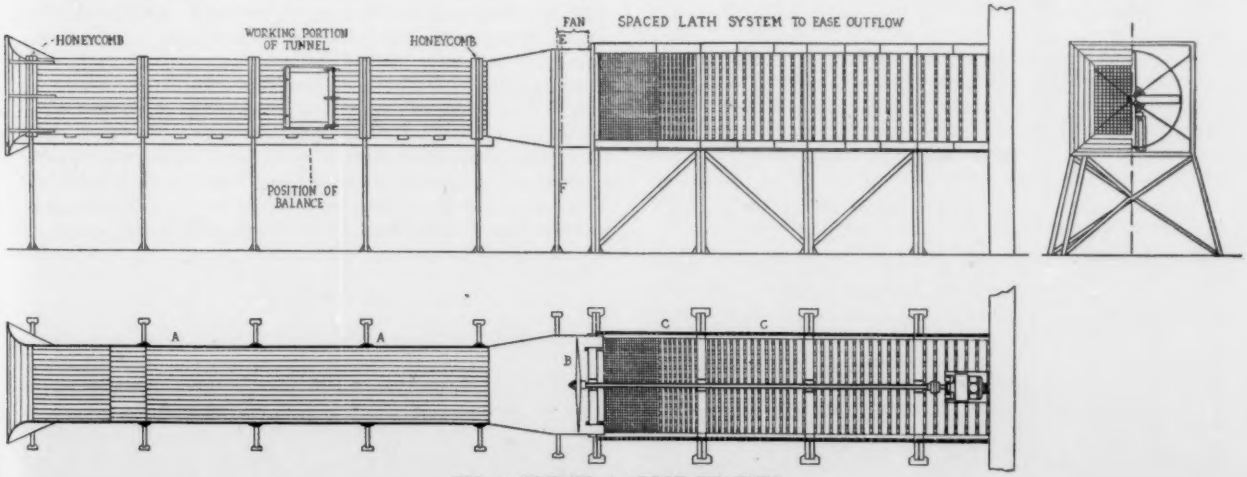


FIG. 1—THE NO. 1 4-FOOT CHANNEL

in addition to the ordinary static pressure p_o, an additional dynamic head given by $(\frac{1}{2})\ \rho v^2$, where ρ is the density of the air in gravity units and v is the speed. This total pressure $p_o + (\frac{1}{2})\ \rho v^2$ is usually transmitted to one end of a pressure gage. At the perforations *CDE*, etc., where the stream is parallel to the surface, there is no additional dynamic head, and the pressure at the outlet F is therefore p_o, the general atmospheric pressure. This is transmitted to the other arm of the pressure gage and balanced against the pressure $p_o +$

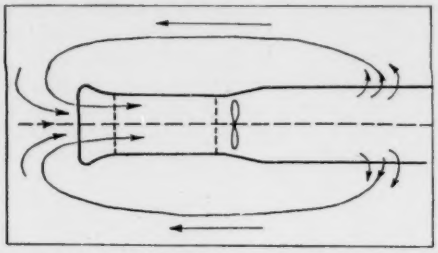


FIG. 2—DIAGRAM SHOWING FLOW OF AIR IN ROOM

$(\frac{1}{2})\ \rho v^2$. The weight of the column of liquid between the two levels in the gage is consequently $(p_o + [\frac{1}{2}]\ pv^2) - p_o = (\frac{1}{2})\ \rho v^2$, and from a measurement of this difference in level the velocity can easily be calculated.

A diagram showing the form of the pressure gage is given in Fig. 4. This difference of pressure between the two cups A and B shows itself by a rising or falling of the meniscus M. This may be compensated for by a measured number of turns of the screw wheel W which alters the relative level of the cups. The alteration of level read off from the scale S is thus a measure of the difference in pressure between the two cups.

A detailed description of the balance in use in most aerodynamical laboratories for the measurement of wind forces on models will not be entered into here, but for the present it is sufficient to state that the principle on which it is based is to balance the moments due to the component wind forces—drag along the direction of the wind, cross-wind force perpendicular to that direction in the horizontal plane, and lift in the vertical plane—by applied external moments. With a model whose weight does not exceed 3 lb. the balance is sensitive to 0.0001 lb. and to much less for very light models.

It is clear that by means of these highly delicate appliances

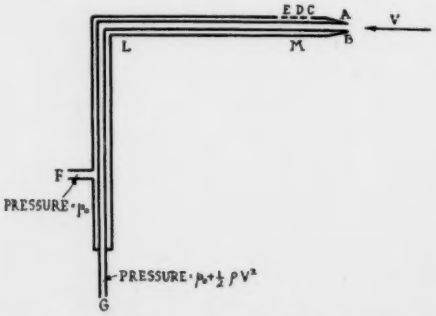


FIG. 3—DIAGRAM OF PITOT TUBE IN AIR SPEED METER

the aerodynamic properties of bodies of all possible shapes, and the modifications due to slight changes, may be investigated to a great degree of precision, but it is also clear that unless the laws of prediction of the forces operating on full-sized machines or parts, at the high speeds of flight occurring in practice, from those measured on models at wind tunnel speeds, are equally precise much of this work would be futile. Even were the laws of transition not known, however, there is still the possibility of deriving useful information by mere comparative methods.

AS TO CHANGES

For example, if it be found that a particular modification—it may be a change in wing section, a change in cross-section of strut, etc.—involves an improvement in the design of the model indicating itself in a more efficient performance, there is a presumption that the same modification will involve an increased efficiency on the complete full-scale machine. How to estimate this increased efficiency in magnitude in the latter case from that measured on the model is, however, a question of much more vital consequence, for upon it will depend ultimately our power of designing aircraft for specific functions and placing reliance on the results. It will be seen that an answer to this can be provided—complete for all practical purposes—by nothing more than an application of the classical dynamical laws of Newton.

In order to clear the ground, certain experimental facts bearing on the question may be briefly recalled. If two bodies of identical shape but one twice the other in size be tested for air resistance in a wind tunnel, it is found that the resistances are equal if the larger model is tested at half the wind speed of the other. Generally, in fact, if the shape of a body be given by a drawing and the length of one part be represented by l which determines the size of the body, then if v be the

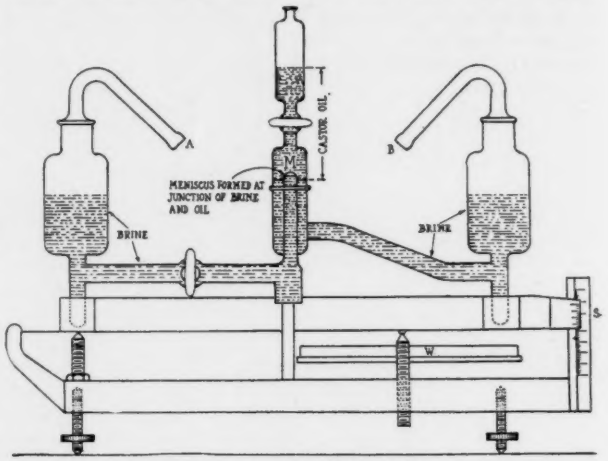


FIG. 4—AIR PRESSURE GAGE

wind speed, so long as $v \times l$ is maintained constant, the resistance remains constant.

This suggests immediately that in air the wind forces exerted on a body are purely a function of the product $v \times l$. We may arrive at this result, however, from very general considerations without reference to experiment. The forces operating on a body can only depend on the size l of the body, its shape, the density ρ and viscosity ν of the air, and its wind speed v. In effect this implies that the expression for the resistance must contain these quantities and these quantities only. We have at the same time the general principle in dynamics that the dimensions of such an expression must be those of a force since it is equated to a force. How then are the quantities l, ρ, ν and v to be grouped together to give an expression having the dimensions of a force? As a mathematical problem this is quite simple and indicates that the resistance R must be represented in the form

$$R = \rho v^2 l^2 f\frac{vl}{\nu}$$

It is particularly to be noted that the exact form of the function $f(vl/\nu)$ is so far indeterminate and will depend purely on the shape of the body under consideration. Two bodies of the same shape but of different sizes moving at different speeds will have the same *form* of expression for f, but vl/ν will have distinct values for each case. As long as the two bodies are moving in air, ρ the density and ν the viscosity will remain

fixed, and it follows at once from this formula that if $v \times l$ is maintained constant the resistance will be the same in both cases in accordance with the experimental fact already referred to. The accuracy of this formula has been subjected to many searching tests, not (be it noted) to check whether the dynamical laws upon which it is based are valid, but to determine whether or not it is justifiable to assume that in all cases the forces depend only on the quantities stated.

WORKING OUT FORMULA

The formula suggests that for all such aerodynamical investigations the most suitable manner of presentation is to plot the resistance coefficient $R/\rho v^2 l^2$ against vl/ν. The curve thus obtained should represent the form of the function f, and all points derived from experiments on bodies of the same shape should, irrespective of the size of the latter, fall on this curve.

The equation

$$\text{resistance coefficient} = R/\rho v^2 l^2 = f(vl/\nu)$$

states that as long as the experiments to be compared are conducted in air, and this is evidently satisfied by comparative aerodynamical tests in the wind tunnel, the force coefficient will depend only on the value of vl at which the experiment is conducted. It follows at once therefore that if experiment enables us to cover a wide enough range of this product the determination of the forces on the full scale could be derived by drawing up an experimental chart showing the variation in force coefficient with vl and selecting the ordinate at the appropriate full-scale value of this quantity.

Fig. 5 gives such a chart for the best strut so far obtained. In this case the resistance coefficient is represented as the resistance coefficient per foot run of the strut, the standard dimension l used in the foregoing discussion, selected in this case to represent the shorter diameter of the cross-section. If in an actual strut $l = 6$ in. $= \frac{1}{2}$ ft. and $v = 120$ ft.-sec.

$$vl = 60. \text{ ft.}^2 \text{ sec. units}$$

and the curve indicates that the resistance coefficient for this value of $v = 0.04$.

A point of extremely general significance is illustrated by Fig. 5. The resistance coefficient, of very large magnitude for low values of vl, falls rapidly, and for large values of vl ultimately approaches a constant value, but when the resistance coefficient is constant the resisting force is proportional to the square of the velocity, and this therefore is the law for a strut moving with comparatively high speed. But this result is not peculiar to a strut; for practically all bodies of aerodynamic shape it is found that if the resistance be measured up to high enough valves of $v \times l$ this force tends ultimately to become proportional to the square of the velocity, and this is probably the case for bodies of the magnitude of those occurring in a full-sized airplane flying at its normal speed. It follows at once that if the wind tunnel tests can be continued up to such a value of $v \times l$ as render the resistance coefficient sensibly constant, the constant of proportionality is at once determined and the magnitude of the forces on the full scale can immediately be estimated.

Unfortunately, however, for the complete success of this method, the disparity between the values of $v \times l$ for the model and for the full scale is extremely great and it is frequently necessary to extrapolate over an extremely large range of $v \times l$. The relative extent of this extrapolation becomes clear from a simple calculation. If the chord of an airplane wing is 6 ft. and its wind velocity 100 ft.-sec. the corresponding value of $v \times l$ is 600 ft.^{2}sec. units, while for a model test on a wing the chord is rarely greater than 6 in. at a wind speed of 60 ft.-sec., giving a value for $v \times l$ of 30. An extrapolation of, from 30 to 600, appears an extremely large range with a probably high degree of inaccuracy, but in practice the error thus occasioned is more apparent than real. In most cases that arise either the curve for the resistance coefficient has become sensibly constant before the limit of the experimental range is reached, or it is rapidly becoming so.

It is at this stage that full-scale experimental investigations on machines under flying conditions play an important part in acting as a check and supply correction or confirmation to the model results. Systematic and continuous comparison has now been carried through for several years and the conclusions have been arrived at, that no very serious errors creep in as a result of these extrapolations, provided certain factors are used with discretion.

A WARNING

One evident source of trouble is possible, however, and must be guarded against. It has been shown that the resistance coefficient depends entirely on the value of $v \times l$ at which the experiment is conducted; but a wider point of view than this can legitimately be adopted. All the phenomena of the motion, the nature of the flow and stream lines, the occurrence and period of the eddies will all likewise depend

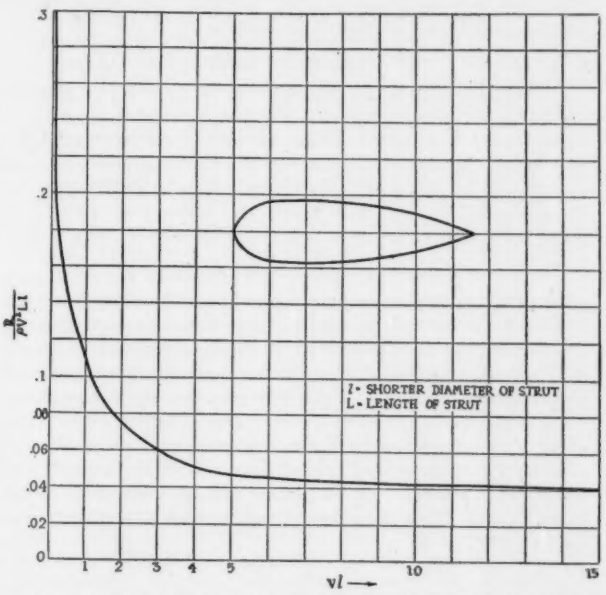


FIG. 5—RESISTANCE COEFFICIENT CHART FOR AIRPLANE STRUT

on this value. Now it is found experimentally that certain critical values of $v \times l$ exist for any given body, in the region of which the nature of the flow undergoes rapid change, accompanied by a simultaneous rapid alteration in the value of the forces originated. It has, for example, been found that certain struts at a given wind speed may indicate as many as three different values for the head resistance according, apparently, to the nature of the flow of air in its neighborhood. The value of $v \times l$ at which this occurs is clearly extremely critical. The three separate resistance curves thus indicated would not be equally stable, and at much higher values of $v \times l$ two of them would disappear. If a false extrapolated value is not to be obtained, it is evident that the experimental range of $v \times l$ in any given case must extend well beyond any region in which such critical values may arise.

There is one branch of aeronautical engineering in which the difficulty as regards scale effect does not arise to any measurable extent; that of propeller design. In this case there is an extra complication in the question which did not enter in that of the steady motion of a body—viz., the fact that the propeller is rotating at a definie angular velocity, say n rev. per sec. in addition to its forward motion. If D is the diameter of the propeller, then, following the lines indicated earlier in the article as regards the form which the forces must take, in this case the thrust and torque, it can be readily shown that these quantities must depend on the quantity V/Dn in addition to VD/ν as before. Ample evidence, however, exists to indicate

that in general the effect of the viscosity term is negligible. This would be so if on plotting the thrust coefficient on a base V/Dn the points corresponding to different values of VD/ν all fell on one single curve instead of a series of such curves. That some form of scale effect might arise is evident on general considerations from the fact that each elemental section of a propeller blade may be considered as of the nature of an aerofoil each portion of which as already seen would produce its own scale effect. Whether these sum up to any appreciable magnitude is quite another matter. Taking a propeller of 6-ft. radius with a mean chord for the aerofoil section 3 ft. from the boss as 5 in., rotating at a speed of 1200 r.p.m., for a static propeller of this nature the value of $v \times l$ would be approximately 160, which is normally well beyond the range at which any scale effect shows itself appreciably. On general grounds, therefore, it is not to be anticipated that the term VD/ν will enter into the equation at all, and this conclusion has been borne out in so many actual cases that have been tested that it may be considered of general application.

SCALE CORRECTIONS

It may therefore be accepted that in order to investigate the properties of propellers, results obtained on models need not be corrected for scale effect, so that the force coefficients, efficiency and other general properties of the propeller will depend merely on the value of V/Dn at which the test is made and experimental means for a model can always be devised to cover the complete range of this quantity required in practice.

NON-DIMENSIONAL COEFFICIENTS

In the foregoing discussion reference has been made in each of the classes of problem dealt with to certain groups of terms by studying the variation of which all the properties concerned may be treated. Such a quantity in the case of problems of the motion of viscous fluids, of the forces on struts, wires and airplane wings is Vl/ν, and in the case of a propeller V/Dn. For every physical problem, whether concerned with aeronautics or not, some such groups of symbols exists with the variation of which, as it were, all the properties may be considered. Now, if we consider the dimensions of these groups of symbols, what do we find?

Quantity	Symbol	Dimension
Speed	V	L/T
Length	l or D	L
Viscosity	ν	L^2/T
Angular speed	n	$1/T$

The dimensions of Vl/ν and of V/Dn are evidently from this table zero, and it follows at once that the value of both these quantities will be absolutely independent of the system of units in which it is expressed, provided all the quantities concerned are expressed in a consistent set of units. An illustration of the same idea from another branch of engineering will be familiar to the reader. The buckling of a homogeneous untapered strut or column, by end thrust takes place when the latter reaches the value

$$F = \pi^2 EI/l^2$$

where E is the elastic constant for the material, l the length of the strut and I the moment of inertia; but this may be written

$$\frac{Fl^2}{EI} = \pi^2$$

and a consideration of the dimensions of the expression on the left-hand side shows that it is non-dimensional. No matter in terms of what units the various quantities are measured, provided they are self-consistent, buckling will always take place when this quantity becomes equal to π^2.

In the same way, if a series of struts, tapered or otherwise, all geometrically identical as regards outline but of different sizes, be tested for buckling as a class, they will all fail when Fl^2/EI reaches some definite fixed value, where EI is the flexural rigidity at some standard section along the length, say the mid-section.

The initial step, therefore, in analyzing any physical or engineering problem by experimental means is to determine the group or groups of non-dimensional terms by whose variation the properties may be studied. Any function of these non-dimensional quantities will itself be non-dimensional, of course, and consequently we have such expressions as

$$R/\rho v^2 l^2 = f(vl/\nu) = \text{non-dimensional quantity} = k, \text{ say.}$$

$$T/\rho n^2 D^4 = F(V/Dn) = \text{non-dimensional quantity} = T_c, \text{ say.}$$

The quantities T_c and k, etc., are non-dimensional coefficients from the value of which at any speed, translational or rotational, and for any size the various force components may be calculated.

The analysis of all these problems centers round a consideration of the value adopted by these coefficients as vl/ν and V/Dn changes. Containing thus the essence of the problem from the theoretical aspect, they embody at the same time the simplest method of representation. The magnitude they adopt for any value of vl/ν or V/Dn is independent of the system of units used, whether in ft.-lb.-sec. or c.g.s. units, while the forces required can be obtained directly my multiplying by $\rho v^2 l^2$ or $\rho n^2 D^4$ in the appropriate units.

A NEW THEORY OF REINFORCED CONCRETE.

IN the Comptes Rendus de l'Académie des Sciences for July 7th, 1919, Mr. Vasilesco Karpen advances a theory to explain the adhesion of concrete to iron in reinforced concrete structures.

This adhesion, he says, is an essential factor in the resistance of reinforced concrete, but its cause and results seem to be unknown. It is usually considered as due to a glue-like action, analagous to the adherence of mortar to brick. Experience, however, does not confirm this view, for if cement is poured on an iron plate the adhesion is far from having the value that it has in reinforced concrete, and if the surface of the iron is smooth or oily, there is no adhesion. On the other hand, tests made with bars embedded in concrete show that adhesion occurs, even when the bars are painted or oiled; evidently there is no action similar to glue in these cases.

The author believes that the unified action of iron and concrete in reinforced concrete structures is due to the friction of the iron against the concrete. It is known that concrete contracts in setting; in so doing it grips the iron which it surrounds and resists attempts to separate the two.

Figures are given showing the results to be expected if this theory is correct, which agree closely with those obtained in practice. It has also been shown by practice that the adhesion of concrete, and its contraction, increase with time. The friction due to the contraction of the concrete around the iron is sufficient to explain the unity of the iron-concrete combination.

When reinforced concrete structures are demolished, the concrete ceases to cling to the iron as soon as it ceases to surround the iron entirely.

In calculating reinforced concrete, it is the general custom not to count upon any resistance of the concrete to tension. The present theory, on the contrary, shows that it is precisely because of the resistance of concrete to tension that it presses against the iron and produces the necessary solidity of the united materials.

By this theory the thickness of concrete required about the iron may be determined from a consideration of the tension, which must not exceed the admissible maximum.

Mr. Karpen's theory also calls attention to the great importance of a knowledge of the coefficient of contraction of cement.

Aerial Passenger Travel at High Altitudes

Aerial "Diving Suits" and "Submarines"

AT a meeting of the "Scientific Commission" of the Aero Club of France, held April 30, 1919, an address was made by Dr. Guglielmimetti with respect to the physiological probems involved in air travel at high altitudes. Dr. Guglielmimetti is a celebrated physiologist and for many years has devoted himself especially to the study of the effects of altitude upon the organs of the human body. He is of opinion that the most feasible method of carrying passengers through the air is at high altitudes in cabins wherein a normal atmospheric pressure is maintained. Such a cabin obviously bears an analogy to a submarine. We quote below a portion of his address from a report in a recent number of *L'Aérophile* (Paris).

Rapidity of movement is one of the factors concerned in the safety of an airplane since it is by this that the latter is sustained in the air. . . . It is at very high altitudes apparently that the amosphere is most propitious to high rates of speed: since the air is lighter it offers less resistance—an avion which travels 150 km. per hour at a height of 5,000 m. is capable of travelling 300 km. per hour at 1,600 m. Moreover the air currents, provided they are favorable, are far more rapid at such altitudes and are regulated by laws which are better known or which are at any rate more general in application than those which regulate the wind at lower altitudes. . . . It lies with the meteorologists to decide at what height new international, transcontinental and transoceanic routes should be laid out.

But can the present day motors carry us at these high altitudes? This is a matter which must be referred to engineers and builders. In rarefied air the motor has need, like the man, of a supplementary supply of air. M. Rateau, a member of the Academy of Sciences, has had the ingenious idea of attaching to the escapement valve a turbine driven by the exhaust gases at a rate of 30,000 revolutions per minute. This motor drives a small centrifugal ventilator designed to compress to the normal pressure the air required by the motor.

At the Aerotechnical Institute of St. Cyr, the Technical Section of Aeronautics has installed an enormous exhaust caisson in which Dr. Garsaux has made obsevations upon the effect of different altitudes upon aviators. Captain Toussaint, the well-known authority upon aero-dynamics, intends to make use of this same caisson in experiments upon motors with respect to the work done at various altitudes.

We now come to the question which interests us specially: is it possible to transport persons in good health to high altitudes in the space of a few minutes without disturbing their health, and if so to what altitude? Is the organism capable of supporting these great variations of pressure and will the diminution in the tension of oxygen permit the organism to survive, with a supply of oxygen?

The researches of Paul Bert have taught us that the troubles comprised under the name of "altitude sickness" proceed from two causes: The sudden variation of the pressure and the influence upon the organism of the rarefied air. Let us explain by examples.

A. If we place two sparrows under a bell jar in which the air has been rarefied, when the barometric pressure within the bell jar has descended to 300 m/m—which corresponds to an altitude of about 7,000 m.—the birds exhibit signs of illness, at 200 m/m (an altitude of 12,000 m.) they stumble and stagger and then fall over and it makes little difference whether this depression has been attained slowly, i. e. in the course of a quarter of an hour, or in only four or five minutes.

If we continue to exhaust the air until the pressure falls to 180 m/m (an altitude of 15,000 m.) the birds become violently agitated and die in a few seconds. If oxygen be now passed into the bell jar the birds immediately recover. It has been proved that the illness thus produced in the birds is due entirely to the lower tension of the oxygen in the blood, for if hydrogen be allowed to enter the bell jar instead of oxygen, the barometer at once ascends and the pressure becomes normal, but the birds fail to recover.

B. When two guinea pigs are enclosed in the same bell jar containing rarefied air, but one of them is allowed to remain at rest, while the other is forced to experience great fatigue (by means of a tread mill, for example) the latter animal will fall ill at a rarefaction corresponding to about 4,600 m., while the former will not exhibit indubitable altitude sickness until a rarefaction corresponding to about 8,000 m. is attained: If the air under the bell jar has been previously saturated with oxygen however, the rarefaction can be carried much further without the slightest symptom of sickness being exhibited. It is evident that the animal at rest represents an aeronaut while the animal forced to exert itself actively represents a mountain climber.

This question of the influence of rarefied air upon the human organism is one with which I have long been intensely preoccupied. Having been born in the neighborhood of the Simplon, which poor Chavez was the first to fly over, giving his life to the cause of the progress of aviation, I climbed in my youth most of the lofty peaks of this mountainous region. I was very often sick but like nearly all Alpinists I attributed this to fatigue, to the lack of sleep in the not very comfortable cabins, or to stomach disturbances. After climbing hour upon hour one is exhausted when one arrives at the top of the mountain, so that one takes but little account of the effect of the rarefaction of the air, and then when one descends he feels better just as he gets over being seasick when the boat stops.

I had a very lively desire to make a prolonged sojourn upon the top of a lofty mountain, in the first case so as to eliminate fatigue from my observations and secondly to see whether it is possible for the human organism to acclimate itself readily to higher altitudes. About this time it was planned to construct a railroad to the top of the Jungfrau (4,000 m.) which gave special interest to the question. The Federal Swiss Council withheld its consent to this project until it could be determined what risks would be run not only by the train crews and the workmen employed in construction, but by the passengers. In 1891, a unique opportunity presented itself—the Jansen Expedition for the building of an observatory at the summit of Mont Blanc at a height of 4,807 m.

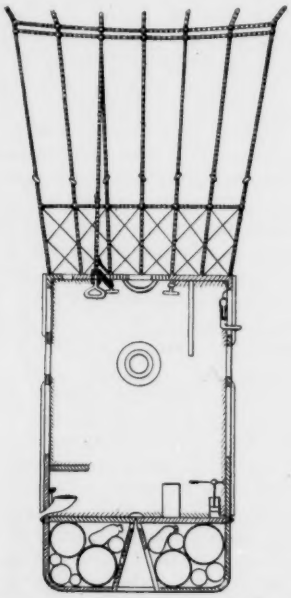
This expedition was to stay for several weeks in the Vallot cabin at a height of 4,600 m. One of my confreres and myself offered to give our services to the members of the expedition—some thirty guides and porters of Chamounix—and to make certain observations upon ourselves.

We all suffered more or less from mountain sickness. This malady is characterized by profound and accelerated respiration (which had but little efficacy), by an increase in the heart beat up to 120 beats per minute, by headache, by nausea, and by general exhaustion. The slightest effort induced a feeling of suffocation and an acceleration of the pulse up to 160 beats per minute. The laborers were employed in digging a tunnel through the summit of the mountain in order to find a rock suitable for the base of an iron observatory, which our colleague M. Eifel purposed to build. Upon observing these men I found that though they were accustomed to the mountain air they were not able to give more than a dozen strokes of the pick or to lift more than ten shovelfuls of snow before finding it impossible to continue and having to be relieved in order to get their breath. Along

about the fourth or fifth day, however, we had all become acclimated except for two porters, who were ordered to descend to the Grand Mulet for fear of serious accident. Dr. Jacottet of Neuchatel, who had requested to take my place for a few days, died in the Vallot cabin the third day after his arrival, from mountain sickness.

But these results obtained in mountain climbing must be compared with observations made in balloon ascents; the latter differ by being more rapid both in the ascent and in the descent and by imposing no especial fatigue upon the organism. It was with the purpose of making such observations that I organized the first series of physiological balloon ascents by means of which it was proved that from 5,000 m. the intimate combustions, the respiratory exchanges in the tissues are augmented to a degree which it was not possible to foresee.

Usually no noteworthy disturbances are experienced in a balloon up to 5,000 m., but from this point onward nearly all balloonists suffer and are unable to resist the effects of the rarefaction of the air except by continuous inhalations of oxygen. In 1912, Lieut. Bienaimé with two passengers reached the altitude of 10,107 m. (the French record); he began inhalations of oxygen at 4,000 m. taking 3 liters per

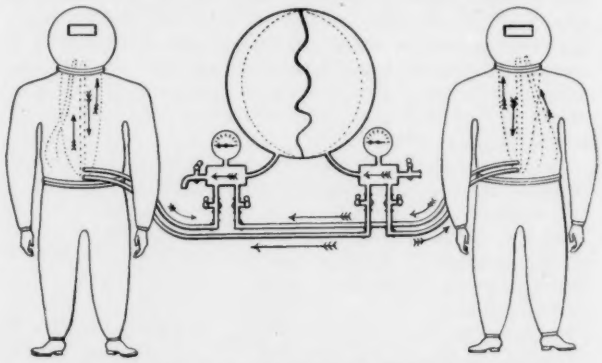


CLOSED CAR FOR HIGH ALTITUDE BALLOONING.

minute and keeping on his mask continuously. He made the ascent without feeling the slightest illness, but one of his passengers who took off his mask every two minutes in order to throw out ballast became unconscious at 8,000 m.; however, he was soon restored by a greater absorption of oxygen.

The world record of altitude belongs to Drs. Berson and Suhring, who ascended to a height of 10,800 m. in 1911. They acknowledged frankly having felt as if they were actually paralyzed, incapable of deciding to make the slightest movement and in spite of their inhalations of oxygen it required all their energy to keep from giving way to an almost invincible sleepiness. As soon as they stopped inhaling oxygen for a few minutes, they suffered increased heart palpitations and began to stagger. An English scientist, Glaisher, with a companion named Coxwell, ascended to a height of 8,860 m. He suffered greatly from balloon sickness and complained especially of the great difficulty of using his arms which felt as if paralyzed. He had not inhaled oxygen and he fainted in the car at about 7,000 m. in height. Another English aviator, Lang, ascended to an estimated height of 9,500 m. with a passenger; the latter fainted at 7,500 m. because the tube leading oxygen into his inhaler was broken.

It is interesting to compare two ascensions made twenty years apart to show the progress made with respect to respiratory apparatus. The first was that of the Zénith which rose to 8,600 m. piloted by Tissandier, accompanied by Croce-Spinelli and Sivel, and the second was the ascent made by Colonel Bolsan and Godard in 1900 to 8,553 m. Paul Bert himself made the prelimintry arrangements in the first case. Together with his pupils, Croce-Spinelli and Sivel, he entered one of the pneumatic bell jars at the Sorbonne and observed that the beneficent action of oxygen enabled them to avoid injury by the rarefaction of the air. Full of confidence in his theory the two younger savants started gaily for their trip on board the Zénith. They carried oxygen with them but it was enclosed in small bags such as are used in cases of illness. Two hours later when the balloon reached earth again the two young men were dead. Tissandier alone survived and he, too, had fainted. . . . According to the log kept by the pilot all three had inhaled oxygen but not until they reached a height of 6,500 m. This was rather late to begin and furthermore, little oxygen was consumed since the bags were found almost full. Crocé and Sivel went to sleep at about 7,100 m. and probably passed away in slumber. . . . When one is attacked by altitude sickness he experiences a considerable prostration and a mental depression which makes him absolutely indifferent to all danger; the will is paralyzed as in seasickness. One has but a single desire—to



DIVING UNITS FOR FLIGHTS AT HIGH ALTITUDES.

be left utterly alone and allowed to go to sleep, even on a bed of snow at a temperature of 20° C. below zero. One feels neither cold nor danger, but to go to sleep in this manner means to wake in another world. Good mountain guides know this and prevent climbers from going to sleep. Undoubtedly Crocé and Sivel became stupefied and lacked both the will power and the strength to catch hold of the oxygen pipe which hung above them and which would have saved their lives.

Compare with this case the ascent made by Balsan and Godard to about the same altitude. Colonel Balsan has told me that he found it beginning to be difficult to work at a height of 6,000 m. though he had commenced to inhale oxygen at 4,000 m. He suffered greatly and found it impossible to carry the oxygen tube to his mouth, his hand remaining motionless at a distance of 10 cm. and his will failing to exert itself. Godard hastily passed the tube to him and in two minutes he was better. When Godard was sick he experienced the same impossibility of action. . . . Dr. Schroetter of Vienna made a sphygmographic tracing at 7,500 m. which was absolutely normal, thanks to the oxygen inhalation which enabled him to perform at this altitude delicate and difficult mental and physical operations.

* * * * * * *

There is little to be said with regard to the symptoms of compression experienced during descent. M. Mallet has told me that he suffered more in the descent from a height of 7,000 m. than in the ascent, and Lieut Bienaimé complained

of experiencing troubles of circulation the day after making his record ascent. . . . But aside from the rarefaction of the air sudden variations of pressure are to be feared . . . finally, the question arises whether ordinary passengers will be able to navigate in the upper reaches of the air. The answer must be—No. All these aeronauts are either young sportsmen or picked men who have been subjected to a severe training which passengers could hardly be expected to undergo. Then, too, there might be found among the latter those suffering from unsuspected troubles of the heart and blood vessels which might cause great variations of pressure to be fatal to them. . . . Further more, for some unknown reason many persons cannot even bear the comparatively low altitude of 2,000 m. In my medical work at Zermatt (1,800 m.) I have seen travellers arrive from Paris and London who felt perfectly well until they had mounted the stairway of the hotel, when they suddenly experienced disturbing and even alarming symptoms; these generally abated after a night's rest but it was sometimes necessary to send such persons into the valley to avoid serious accidents.

* * * * * * *

Let us now consider suitable remedies for altitude sickness.

Improved and automatic respiratory apparatus may suffice for aviators whether sportsmen or military men, but if passengers are to be transported it is hardly feasible to think of providing them with similar masks, not only because these would considerably interfere with the pleasure of the voyage, but because they do not offer a sufficient guarantee against illness. . . .

By means of diving bells, diving suits, and submarines, man is enabled to live in a *milieu* which provides no element to satisfy his lungs. Why could not similar apparatus be devised for use in the upper regions of the air? The accompanying diagrams show devices proposed to meet this end. The first is a closed cabin in which both passengers and pilots are surrounded by a normal atmospheric pressure which can easily be maintained by means of a pump. The weight of such a cabin holding twelve persons need not be more than two or three hundred kilograms, if composed of duralumin. The technical problems involved appear to be theoretically simpler than those which have been solved in the case of diving suits and submarines; even at the highest altitudes the difference of pressure between the inside and the outside air would not exceed more than about half an atmosphere, while the walls of a submarine are required to support a difference of three or four atmospheres. Even supposing that an accidental crack appeared in the walls of the cabin so that the latter was unable to maintain the constant pressure, it would always be easy to descend to a lower altitude. . . . As a matter of fact such a cabin is now being studied by several builders and by the Technical Section of Aeronautics.

I may terminate these remarks by mentioning a project for a closed car and an aerial diving suit presented before the French Society of Aerial Navigation as long ago as 1871. . . . This car, proposed by Louis Tridon, was composed of solid and flexible portions. The solid portion was composed of a floor and roof of basket work. The roof served as a maneuvring car. At a high altitude the aeronaut was supposed to descend through a manhole into the lower car in which were placed compressed oxygen and cloths soaked in lime water to absorb the carbon dioxide of the breath.

In 1900, M. Andrieux presented to the same Society the model of an aerial diving suit, consisting of air tight canvas. A special system of tubes fed by a reservoir of compressed oxygen served to maintain around the aeronaut a sufficient pressure to cause the air to circulate in such quantities as to ensure comfortable respiration.

Since these different questions concerning the navigation of the air at high altitudes are intimately connected, and interest physicians and meterologists as well as builders, I have requested the Scientific Commission of the Aero Club kindly to invite various specialists to be present at our meetings in order to obtain an exchange of views upon this subject . . . which I hope may lead to discussion which will be of advantage to the progress of aeronautic science.

The Instinct of Orientation in Ants

The Operation of the Homing Instinct

By Dr. Rudolf Brun, Assistant in the Nerve Polyclinic of the University of Zurich

ANTS are peculiarly adapted to the study of distance orientation for two reasons: First because of their settled and social manner of life which forces them constantly to return to a definite starting point, *i. e.*, the nest, after all their expeditions, and secondly because, unlike bees, they lack wings, and it is thus easier to follow their movements during the course of experiments.

The correct understanding of such a complicated biological process as is presented by the distance orientation of ants naturally requires an exact knowledge of the anatomy and physiology of the organs of sense therein concerned as well as of the association apparatus in the brain connected with these organs. Hence I will begin my remarks by recalling the essential features of these.

The senses concerned in the orientation processes of ants are those of smell, of touch, of sight, and of kinesthetic registration. With respect to the last mentioned our information must be exclusively gained by experimental physiological analysis. With respect to the functions of the other senses the mere anatomical structure of the organs concerned furnishes us with at least partial data.

The sense of smell is by far the most important possessed the odorous objects, which are perceived at the same time by ants from the biological point of view. It is of essential importance for what I have called extero-ceptive orientation in space, because its peripheral end apparatus is localized superficially upon the symmetrical and extremely mobile jointed antennae. The sense of smell in ants belongs, therefore, like the human eye, to the *relational* senses, *i. e.* it is primarily a contact-odor sense which does not perceive the emanations from various objects as does the human nose in a diffused mixture, but, on the contrary, in a quite definite arrangement in space, corresponding to the forms possessed by the tactile hairs of the feelers. It is upon this consideration that Forel[1] has based his brilliant *contact-odor theory*, or, theory of the topo-chemical tactile sense according to which ants become aware of sharply defined "odor forms" by means of their feelers. They are able to distinguish, for example, between round and square odors, hard and soft odors, elliptical and spherical odors, and they store up in their memories associated topo-chemical engram-complexes corresponding to these odor forms in the same arrangement with respect to time and space in which they were originally perceived. Forel expressly emphasizes the fact, however, that ants can naturally make use of these topo-chemical associations only to a very

*Translated for the SCIENTIFIC AMERICAN MONTHLY from the *Biologische Centralblatt* (Leipzig).

[1]Forel Experiences et remarques critiques sur les sensations des insects.—Rivista di Sc. Biol. II and III, Como 1900-1901.—Die Psych. Faehigkeiten der Ameisen, 2. Aufll., Reinhardt, Munich 1902.—Sinnesleden der Insekten, ebend. 1910.

limited extent corresponding to the absolute smallness of their brains. . . . In comparison with the contact-odor sense the capacity for distance smelling is obviously only slightly developed in ants it is easy to convince ourselves by a simple experiment that ants are incapable of scenting for a distance of more than a few centimeters even highly fragrant substances which are particularly appetizing to them.

The sense of sight exhibits in ants as in most insects a series of peculiariies which indicate beforehand that they probably function in the matter of distance orientation in a manner different from that of the eyes of vertebrates. According to the Mueller-Exner theory of "mosaic vision" the facetted eyes of insects produce a single upright mosaic image (apposition image), whose distinctness depends primarily upon the number of the facets and secondarily upon the length and narrowness of the separate ommatidia, as the single facets of such compound eyes are termed. The eyes of the best seeing ants, those of the workers, possess a comparatively small number of facets[2] and comparatively short ommatidia. Their distance point, which usually depends upon the curvature of the lens of the cornea, is reduced in most varieties to a few millimeters or at most centimeters from the eye. The immovability of facetted eyes also has the consequence that the attention of the resting insect can only be attracted by moving objects. For this reason the eyes of ants appear to be usually suited only for the perception of large moving objects in their immediate neighborhood (Forel). On this account is was formerly generally believed that the sense of sight must play only a very subordinate rôle in distance orientation among these insects. We owe the correction of this error mainly to the work done by Santschi.[3] . . .

The question as to whether ants are able to "hear" appears to be still undecided in spite of much research. The peculiar so-called "chordo-tonal" organs extended inside the tibia have been repeatedly referred to as organs of hearing; in case, however, these are really capable of receiving true sound waves, they are probably confined to the perception of those very delicate chirping sounds or "stridulations" (in the immediate vicinity) which many ants produce by the rubbing together of certain parts of their armor of chitin. As regards "static organs," finally, these have not as yet been shown to be generally possessed by insects.

If we compare the sense functions just mentioned with reference to their direct realm of influnce we shall readily see that none of them is capable of a direct perception of the nest (or rather of the phycho-physiological sensation-complex "nest") from a greater distance than one meter at most. It follows from this that every distance orientation of ants of a greater distance must be indirect, i. e. it must not be produced by a sensory stimulus complex, but in "the sensorium" of the insect, merely as an engram of the goal, by the aid of intermediate direction signals secondarily associated with this engram of the goal. The question here arises whether it is possible to ascribe to such minute creatures as ants such a degree of the capacity for plastic recording and association. Many authors, among them Bethe[4], have, as we know, positively denied the existence of an individual memory in insects and where their experiments have appeared to contradict these preconceived opinions, they have preferred to take refuge in some physiologically inexplicable "unknown power." But before we follow these authorities into the dark domain of scientific mysticism it may be well to inquire whether there may not exist anatomical structures in the central nervous system of the higher insects capable of being regarded as furnishing a morphological foundation for biologically demonstrable plastic nerve activities.

[*Limitations of space oblige us to omit the detailed description which here follows of the brain of the red ant, merely saying that the author appears justified in his contention that the mushroom shaped bodies or Corpora pedunculata may be regarded as a sort of cerebrum.*—EDITOR.]

The marked development just described of the *Corpora pedunculata* is found distinctively only in the phylogentically recent social Hymenoptera (ants, bees, wasps), and in these only in the female and worker castes, which are alone in exhibiting those higher plastic capacities referred to above. In the much more stupid males these organs, as Forel first showed, are always essentially smaller and but slightly convoluted, often, indeed, merely rudimentary. While in the non-social insects they exist at best, if at all, as simple, stratified dorsal protuberances. Thus we look for them in vain in the stupid flies, those proletarians of the insect world. . . . In my opinion, therefore, we may conclude that we have in the *corpora pedunculata* . . . a central association apparatus of high functional value, which may be considered to some extent as an analogue of the cerebrum in vertebrates. . . .

1. *Mass Orientation.*

This is usually, though not always, an orientation along a well defined road, which is usually indicated by a chemical trail, more rarely by actual beaten roads made by the ants. We are chiefly interested here in orientation by an odor trail. . . . this usually exhibits the following phenomena: Along a stretch of 5, 10, or even 100 or more meters, an unbroken column of ants is seen going back and forth between the nest and the goal, the latter usually being a colony of plant lice. Each ant closely follows his leader without varying a finger's breadth from the path and constantly touching the ground with its antennae. That the ants actually follow an odor trail deposited upon the ground is proved by a simple experiment made by the Geneva savant, Ch. Bonnet, more than a hundred years ago: *i. e.* if a finger be drawn squarely across the path the ants on both sides this break in the trail immediately stop and feel anxiously about with their antennae until at last one of them slowly and hesitatingly ventures to cross the obstacle, whereupon the caravan gradually resumes its course. Furthermore, Santschi discovered in 1911, by close observation with a lens, that many ants actually marked the trail by depositing from time to time a minute drop of a secretion which apparently issues from the anal glands. I, myself, have proved the tenacity of this trail odor in the following manner. I allowed ants (*Lasius niger*) to wander through a system of communicating glass tubes, from time to time removing one of the tubes and later replacing it. I found that the odor clung to the removed tubes in almost undiminished strength for 2, 4 or even 8 hours; it was not entirely removed even by blowing through the tube or by washing it for five minutes in cold water. To entirely remove it I had first to wash the tube and then rub it out with raw cotton.

In 1898, Bethe made the remarkable discovery that ants are also able to distinguish between the two directions of the trail by purely olfactory means. In consequence of this discovery the question of orientation by odor has become one of the most difficult and disputed problems of insect psychology.

Bethe led a trail of *Lasius niger* over three narrow boards a, b, c, placed in line between the nest and a colony of lice. When one of these boards, b, Fig. 1, was reversed in position there was always a marked disturbance at each end of the reversed board, although the trail itself was not interrupted. On the other hand a mere exchange of place between the boards caused no disturbance so long as the direction remained the same. Bethe then placed b and c side by side, b in the same direction and c reversed. The natural consequence was an entire interruption at the point where c had formerly been on the part of the ants returning to the nest.

[2] In the *Formica rufa*, one of the kinds which sees best, there are only 600, for example, whereas there are 20,000 in many of the Libellae.

[3] F. Santschi, Obs. et Rem. Crit sur le Machanisme de l'Orientation chez les Fournis. Revue, Suisse, de Zoöl. 1911.—Comment s'orientent les Fourmis. Ibid 1913.—L'oeil composé considéré comme organe d'orientation chez la Fourmi. Rev. Zoöl. Afr. III, 1913.

[4] A. Bethe, Duerfen wir den Ameisen u. Bienen psych. Qual. Zuchreiben?—Arch.f.d. ges. Phys. Bd. 70, 1898.

Those travelling away from the nest upon the board a, on the other hand, all passed from a on to b (which was not reversed), sought the broken trail at the end of b for awhile, and finally wandered on to c and back towards a. Here a new confusion arose, followed by a new passage to b and back again to c. In short the little creatures were "caught in a vicious circle."

From these remarkable results Bethe concluded that the chemical odor particles of the trail possess a polar structure . . . the olfactory perception of this polarization is supposed to release in the ants "a chemo-reflex" which forces them to follow the respective trails from the nest to the colony and vice versa only in the direction of their "polarity."

This polarization hypothesis has found little support in spite of its fascinating simplicity. . . . Wasmann[5] especially refuted it as being unfounded both in theory and in fact. . . . He pointed out that since the ants are constantly travelling in both directions, any polarization of the outgoing path would

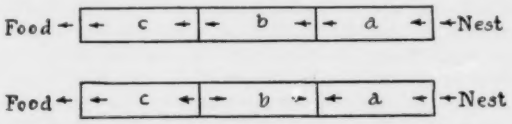


FIG. 1. REVERSING A PART OF THE ANT'S TRAIL.

promptly be counteracted by the reverse polarization of the return trail, unless the two trails were sharply separated from each other, which is never the case.

Wasmann explains the phenomenon by supposing that the ants are able to distinguish between these "odor forms" of their footprints, which naturally point in different directions when going and when coming. If we assume also that in the first direction they probably have a certain nest odor while on the back path they have more of the odor of the colony of lice, we see that both directions of the trail would be clearly indicated by such a combination of two differently directed trail forms with two different kinds of odor. We may find a human analogy by supposing that all the travellers between a city and a village wore shoes which were painted red and which left red footprints behind them, while all the people going in the other direction wore blue painted shoes and left blue footprints.

It must be admitted that this footprint theory seems to explain the phenomenon satisfactorily at first glance; when

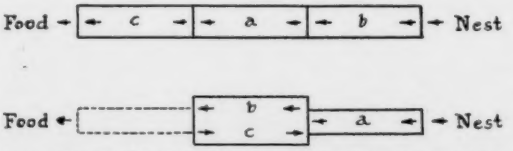


FIG. 2. TRANSPOSING A PART OF THE TRAIL AND TURNING IT BACK ON ITSELF.

we remember on the other hand that an ant has six feet and that often there are thousands of these six-footed tracks mingled in grand confusion on a single trail, it seems to say the least, a very rash and artificial theory.

Forel on the other hand supposed that the chief importance resides not in the trail itself but in the space to the left and to the right of it; it is his idea that through repeated journeyings over the same road the successively encountered objects to the right and the left of the trail gradually caused the ants to acquire a certain sum of associated topo-chemical engrams. In other words they gradually form a map of the path outlined by the objects to right and to left, to the front and to the rear. Naturally, therefore, when part of the road is suddenly whirled around so as to point in reverse directions they are inevitably disoriented, since the odor-forms encountered to left and to right no longer coincide with those recorded in memory.

In my opinion even this brilliant theory is not entirely satisfactory. . . . I therefore determined to study this remarkable phenomenon under variable conditions, so as to be able to analyze it more precisely. My experiments which I have designated as a "Mnemonic Investigation" consisted in causing ants to make journeys now over a path "known" to them (in Forel's sense) and now over an unknown path, so as to observe their manner of determining direction. For this purpose I made use of a colony of the shining black *Lasius fuliginosus* which travel almost exclusively by means of odor trails, dividing them into two parts, A and B. Part A was placed in a temporary container and part B established in an artificial observation nest whose glass exit tubes opened upon a narrow paper bridge 1 meter long (Fig. 3). This bridge ran across the center of a circular experiment table to a small platform, Pl. The central portion of the table together with the portion of the bridge crossing it could be revolved.

In order to study a purely olfactory orientation it was necessary to exclude all other kinds, beginning with optical orientation. To this end I worked inside a dark tent having black walls and ceiling and provided with "bipolar" illumination, *i. e.* having two sources of light placed symmetrically to the right and the left of the table across the axis of the bridge. With this method of illumination it is obvious that an ant travelling from the center of the bridge must receive strictly

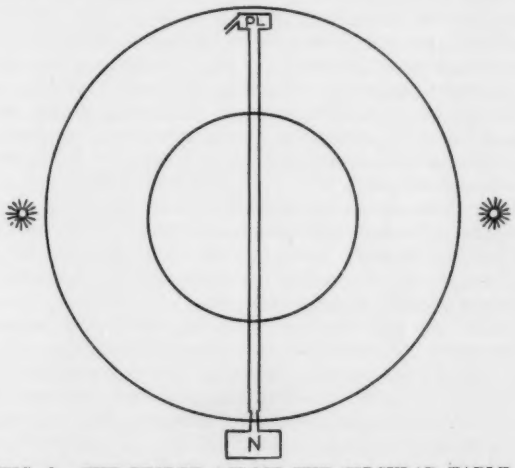


FIG. 3. THE BRIDGE ACROSS THE CIRCULAR TABLE

symmetrical light impressions in both eyes, whose sensory localization remains the same whether it travels towards the nest or in the opposite direction; thus no *relative* direction would be indicated by the source of light.

I placed honey upon the platform and the ants promptly commenced a brisk expedition towards it, which was in full swing a few hours later. I thereupon made the following experiment:

I. By means of a lead pencil I took up ants on the platform which were sated with honey and ready to return to the nest and let them descend in the middle of the bridge, but headed in the wrong direction. Result: All the ants continued for a time in the wrong direction, then stopped, ran back and forth a few times in each direction, and finally set out definitely towards the nest. Thus they seemingly acted according to Forel's hypothesis—as if trying to ascertain the topo-chemical succession.

2. The ants were allowed to descend nearer the nest. The same result, but the right direction more quickly found.

3. Descent in middle, but headed towards nest. Only a few wavered, the others following the right direction hesitatingly at first, but with increasing certainty.

II. I repeated the experiments with ants from A, to which, of course, the bridge was quite unknown. To secure a uni-

[5] Wasmann, die Psych. Faehigk. d.Ameisen. II Aufl.—Schweizerbart'scher Verlag (E. Naegele), Stuttgart, 1909.

form reaction I took only ants already carrying larvae, whose goal was obviously the nest. Result the same, *i. e.* mistaken direction at first, regularly followed by a correction. Hence this olfactory orientation cannot be based upon the existence of a topo-chemical engram-succession, and Wasmann, too, is wrong, since the correct direction was never found until repeated wavering in the two directions had occurred.

III. I next replaced the honey by a quantity of larvae, which the ants at once began to carry to the nest. I was astonished to find that now all the ants which were headed wrong when they descended continued in the false direction without the slightest wavering—in other words, in journeys in which the brood is carried for a long period of time an olfactory indication of direction seems to be entirely lacking. This was even more apparent when I put the larvae on the middle of the bridge instead of on the platform. The ants coming from the nest stopped short when they got to the pile of larvae, ran around it, finally seized one and started home. But fully half went in the wrong direction and arrived at the platform, where they hunted a long time for the door of the nest, and finally turned back towards the nest or else became hopelessly confused. (It must be recalled that all these experiments were conducted in the dark tent with bipolar lighting.) I then placed a "breastwork" of stiff paper (5 mm. high) on one side of the bridge; this was at the left of the ants leaving the nest—at the right of those returning. I left this landmark standing 3 days and then repeated the experiment with the "larvae in the middle." This time not more than a fourth or a fifth of the ants started in the wrong direction, and most of these corrected themselves as soon as the antennae chanced to touch the landmark. These stopped short, struck square across to the other side, stopped again and **turned about!** This remarkable proceeding was so constantly repeated that all idea of chance is excluded. I then removed the landmark and at once 50 per cent of the insects went wrong, only a few turning about or ever stopping. This evidently proves that *ants can distinguish the topo-chemical impressions upon the left side of the body from those on the right, and that they are capable of associating such constantly localized one-sided impressions with direction.* . . .

I next repeated Bethe's reversing experiment upon my bridge path . . . with the following modifications: At the west end and the platform end of the bridge I placed movable strips of paper equal in width and increasing successively in length. After the travel had continued to pass over these for several hours, I first reversed each strip where it was, and then exchanged two strips, one of which was reversed while the other was not. . . . The results follow:

1. In this case as in the memory experiments the Bethe phenomenon is entirely negative in the "brood expedition," since all of the ants continue to travel without the slightest pause in the same direction, both over the reverse strips and over the interchange strips.

2. On the other hand the phenomenon is entirely positive upon the "food expedition," though with the following important peculiarities:

a. Contrary to Bethe's supposition there was a strong reaction when the nest-strip was exchanged with the platform-strip, but without either being reversed.[6]

b. The reaction increases in proportion with the increasing length of the reverse section of the trail.

c. It is more marked after the exchange of the reversed pieces than after the mere reversal in the same position.

d. It is more intensive at the nest-end than at the food-end.

e. Finally in both places the ants travelling from the nest towards the food constantly react more intensively than the home-returning ants.

In my opinion all these facts can only be explained by the hypothesis *that the odor complex of the ant trail exhibits in the course of its continuity a successive decrease of intensity of certain components, and this apparently, in both directions.* Upon leaving the nest thousands of ants carry with them the nest odor clinging to the feet and antennae and with gradually diminishing intensity, while on the return trip they carry the honey odor in the same manner. Hence there is a strong nest odor near the nest and little or no honey odor, while at the goal the comparative intensity of the two odors is reversed. Thus, if we reverse a section of the trail in the vicinity of the nest the ants arriving there from the nest will suddenly perceive a strong variation of intensity, the longer the reversed section, the greater being this variation. If in spite of this they cross the reversed piece, instead of an increasing honey smell they will detect an increasing nest smell, which is bound to disorient them completely. In the neighborhood of the honey the case will be similar with respect to the odor of the latter, but the honey odor is probably much less intense than the smell of the nest, in which the ants spend a greater part of the day. Furthermore, in the neighborhood of the goal the ants are no longer capable of reacting to the same degree to the smallest variations of the intensity, partly because of the fatigue of the organs of smell and partly because having completed the greater part of the journey they are more confident of the matter. In this manner we can explain the much slighter reaction of the ants in the neighborhood of the goal compared with that at the door of the nest. The memory impulse will be much more effective in the home-coming ants since all of these have already crossed the road on the outgoing journey and are probably, therefore, in the possession of certain actual engrams both of the general topo-chemical constitution of the path and of its length. On this account it is no longer necessary for them to follow the trail with their antennae so slavishly as upon the outgoing journey, and for this reason the more delicate variations of intensity in the constitution of the odor trail may readily escape them.

The matter is essentially different in the case of the "brood expedition." Here the odor of the goal is the odor of the larvae and consequently, because of the transport of the latter, the whole trail will exhale this odor with the same strength as that of the goal. Hence all sections of the path will gradually acquire a completely homogeneous brood-smell . . . which will show no perceptible decrease of intensity either in one direction or the other.

. . . But the olfactory factor is only one component—though a very essential one—of the complex mechanism of orientation. The other factors involved we shall now examine experimentally in the orientation of individual expeditions.

2. *Orientation of Individuals.*

Forel blinded the eyes of red ants by covering them with black varnish and found that the insects thus treated had great trouble in following the trail, constantly wandering to one side. Both Forel[7] and Fabre[8] agree, furthermore, that the armies of the Amazonian ants (*Polyergus rufescens*) when returning from their raiding expeditions are not affected by flooding of the ground in the neighborhood of their dwellings. Miss Fielde[9] noted the same phenomenon when she forced home-coming ants to swim by covering the ground with water. . . . All these authors came to the conclusion that sense of sight, or at any rate a certain degree of visual memory of locality, plays an essential part in orientation, at least with the kinds of ants mentioned.

It has long been known, too, that ants often make single expeditions, sometimes of considerable extent, from the nest, but it was supposed that these single wanderers followed their own trail back. This unfounded supposition was first experimentally disproved by the French psychologist, H. Piéron.[10]

[6] This contradiction to Bethe's results may be explained by the fact that in my experiments the two sections were much farther apart than in Bethe's experiments.

[7] Forel, Fourmis de la Suisse, Geneva 1874.

[8] Fabre, Souv. Entom. II; Paris, Délagrave 1879.

[9] Fielde, Experiments with Ants Induced to Swim. Proc. Acad. Nat. Sciences, Philadelphia, 1903.

[10] Piéron, Du Role du Sens Musc. dans l'Orientation des Fourmis. Bull. Inst. Gén. Psych. 1904.

He removed ants travelling singly homewards from a given point X to a second point X_1, several meters to one side (Fig. 4). The ants thus transported placidly continued the journey, no longer in the direction of the nest, but in a direction exactly parallel to the one originally followed until they had covered an amount of distance which on the original path would have brought them to the nest; they then began to describe confused "concentric curves" as if seeking the nest. In other words they behaved exactly as if they had an internal compass by means of which to find the absolute direction and likewise a pedometer to indicate the distance covered!

This interesting phenomenon led the Algerian engineer, V. Cornetz,[11] to study individual expeditions of ants. He em-

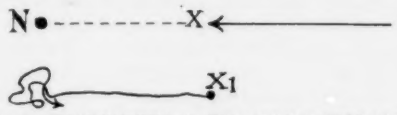


FIG. 4. TRANSFERRING THE ANTS LATERALLY

ployed the graphic method, marking the course pursued by the insects upon the ground, making precise measurements of this and reproducing it geometrically on a reduced scale, thus obtaining an exact representation of the entire journey. The first thing discovered by him was the fact that the individual travellers do not make use of a scent trail, since the ground in front of them can be thoroughly swept by a broom without causing them the least concern. The expedition is by no means an irregular wandering about, but commonly has a definite main direction, to which the insect returns with great precision after occasional wanderings to one side or the other. *The return trip is never identical with the outgoing trip*, though lying not far away and being in the main parallel. It sometimes occurs, though rarely, that in the course of the journey an ant goes in two or even three different main directions which are usually perpendicular to each other. But on the return journey the diagonal of the triangle or polygon is never taken, but the various main axes are successively followed in the reverse arrangement and for approximately equal distances. When the ant has approached the nest within a certain distance (which varies in length) it usually suddenly abandons the main direction (which is commonly somewhat erroneous) and starts more directly towards the nest; generally, however, it goes a little bit past the mark and this requires a fresh correction. This may be repeated several times so that the ant is really encircling the nest with concentric curves which grow constantly narrower until finally the entrance of the nest is found. It is interesting to note that these corrections always succeed each other in the same direction from the given point (but only from this point). If, for example, an ant which has corrected its path from Y to Z (Fig. 5) is put back to the point Y it returns to Z, but if it is put at any point off the road between Y and Z it will run at random in any other direction.[12]

The parallel course observed by Piéron has been noted by Cornetz in the deepest forest shade or after transportation from the sun to the shade, or vice versa. On the other hand the phenomenon is usually entirely lacking when the transpor-

FIG. 5. THE ANT CORRECTING ITS COURSE

tation is to territory of a different sort, *e. g.* from sandy ground to a meadow, and in my opinion this is a proof that the ants record in the brain the general conformation of the ground observed during their expedition. After a primary transportation away from the nest Cornetz always found the ants to be entirely disoriented, with the exception of a single case which occurred as follows: An ant trail ran squarely across a country road; the nest was situated under a stone at the edge of the sidewalk. When Cornetz sought the place a few days later the trail of ants had all gone in. He picked up a few ants directly at the entrance of the nest and placed them in the middle of the road, a few meters to one side of the previous trail. The ants ran at once back to the curb in a direction exactly parallel to the old trail and then turned to the left exactly as the first trail had done.

In spite of the admirable qualities of Cornetz as an observer he fails in interpretation. . . . Thus we find him uttering the following amazing opinion:

"The orientation of individually wandering ants seems to be quite independent in principle of any sort of sensory continuation points in the external world. They seem rather to follow, by means of some unknown absolute inner sense of direction, a course which is established in the sensorium of the insect during the outgoing journey and which enables it to follow such a previously obtained absolute direction, even after the lapse of several days."

This view has recently been attacked and refuted by Dr. Santschi,[13] a myrmecologist, living in Tunis. Santschi believes that every oriented locomotion is necessarily related to some source of stimulus in the outer world. When, therefore, an ant which has been removed from point X to X_1 immediately resumes its former direction there can be only one logical explanation, namely, that the stimulus complex which is tropically effective at X must be present also at X_1 in exactly the same special relation to the sensory perception apparatus of the animal. We have such an omnipresent tropical stimulus coming from the same direction at any given place in a source of light, particularly the light of the sun. Everything which we know in regard to the anatomy and physiology of the eyes of insects appears to Santschi to favor the hypothesis that individually wandering ants orient themselves by light.

We have seen that facetted eyes are chiefly adapted for seeing motions, *i. e.* relative alterations of locality in the retinal image. If this is correct they appear to be also adapted to the localization (during the movement of the body in a straight line) of large distant stable objects or distant direct sources of light in an uncommonly exact manner. . . . Thus in order to keep to a definite straight direction the animal only needs to keep the image of the sun in certain facets. And furthermore, if it so places itself upon the return journey that the image of the sun constantly strikes the diametrically opposite corresponding facets of the other eye, it is clear that the return path will be parallel to the initial path and will, therefore, lead pretty nearly to the starting point. From these premises Santschi formulated his brilliant theory as follows:

The facetted eyes of ants act in a measure as light compasses, thus enabling them to pursue a given direction in a straight line and also to return with certainty to the starting point. The method of operation consists of an exact sensory localization of the source of light during the outgoing journey and also during the return journey by means of a sensory reversion of the said localized light impression upon the diametrically symmetrical sensory surfaces. The parallel journey observed by Piéron is nothing more, therefore, than a virtual orientation towards the source of light. Among the numerous experimental facts by which Santschi supports this theory, I will quote only the mirror experiments.[14]

In the path of individual home-going ants Santschi shaded the terrain by a large screen and then projected the image of the sun to the other side by means of a large mirror. The result was always the same—the insect immediately turned about and ran in the opposite direction, *i. e.* away from the

[11] Cornetz Trajets de Fourmis et Retours au Nid. Nem. de l'Institute gén. Psych. 1910.

[12] Cornetz, La Connaissance du Nonde environnant son, gite pour une fourmi d'espéce supérieure. Rev. d. Idée, 1912.

[13] Santschi, Comment l'Orient les Fourmis. Rev. Suisse de Zoöl. 21, 1913.

[14] Revue Suisse de Zoöl. 19, 1911.

nest as long as the false sun was shining. If the mirror was so turned that the false projection of the sun was at right angles the ant followed a corresponding direction at right angles to its former one. . . .

But Santschi was not the first to prove the orientation of ants by light, though he gave it a more exact physiological basis. More than thirty years ago Lubbock[15] showed that ants immediately reversed their path when the source of light is reversed. . . .

I have obtained similar results by other methods. . . . Over an ant which was running across a playground covered with sand in a direction almost exactly opposite the sun I placed a small round cover. I kept the ant captive exactly two hours; when I removed the cover at five o'clock the ant was resting motionless in the center of the little cover. It turned itself slowly about and travelled again almost in a straight line over the sand in the direction of the flower bed at whose edge its nest was situated. But the line of the return path deviated from the outgoing curve by 30° to the right, i. e. by exactly as many degrees of an arc as the sun had travelled to the left in the firmament during the two hours which had elapsed (Fig. 6). I repeated the experiment varying the time. In every case the angle of deviation of the return curve corresponded to the solar angle concerned, with only a very slight amount of error. It is not surprising that the ants should not have taken into account the time of their imprisonment and the fact that the sun had travelled farther across the firmament in the meantime—on the contrary, it would

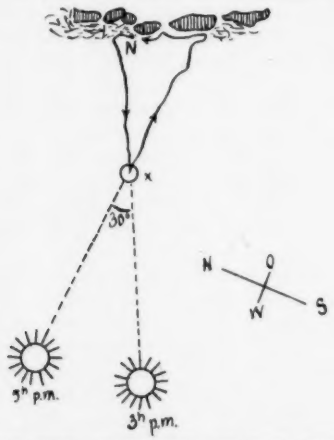


FIG. 6. HOW THE DIRECTION OF THE SUN AFFECTS THE COURSE OF THE ANT

be quite wonderful if they were capable of arriving at this logical conclusion.

On the other hand this fixation experiment failed almost entirely in precisely those varieties of the species *Formica* which are provided with the best eyes and which also stand the highest phsychologically. These ants resumed their former direction after the fixation without perceptible deviations. Many other things indicate also that these ants usually orient themselves on their individual journeys in a much freer manner than is compatible with the light compass theory. I rarely succeeded with these in obtaining a typical parallel journey, especially when the lateral removal was only a few meters in extent, since in this case the ants not seldom cancelled the lateral deviation by a corresponding cross course. In short the impression was obtained that the distance orientation was here largely secured by *differentiated visual complexes*, possibly by the more or less indistinct perception of certain large objects at a distance, such as trees and houses, with whose position that of the nest was associated. This hypothesis is favored by the results of certain other experiments which I undertook with the *Formica sanguinea*, originally with the purpose of studying the influence of kinesthetic angle-registration. I drove certain ants away from the nest forcing them to go to the left upon the above mentioned area of sand and obliging them by my hands to follow a patch curved in a certain definite manner which I had previously drawn in the sand. To my surprise after accomplishing such a "forced journey" the ants always returned at once and in the most direct line to the nest, although the point where I let them go free was often quite far from the nest—20 to 34 meters, and the return journey was made after a right-angled forced journey, not by means of successive reversions of the two legs of the way, but in a diagonal direction, *i. e.* with a direct completion of the polygon (Fig. 7). I then forced the ant to follow large curves, or, in other cases, very complicated many-angled curves including many opposite directions; in the first cases the return was made promptly along the secant and in the second cases along the approximate resultant of the original curve, *i. e.* pretty directly in the direction of the nest. When the ants were transported directly to the end of the curve without having previously followed it, they appeared to be completely disoriented—a proof that the direction engram concerned was actually obtained during the forced journey. I then blinded several ants and took them over a simple forced journey consisting of two axes; they were absolutely incapable of making the return journey, only a single insect making a laborious attempt to go back over the second leg of the way. Hence the diagonal path taken cannot be based upon a complicated association of kinetic angular engrams. Finally I made an ant take a forced journey having two axes and of very great length, extending far beyond the sandy area. The result was that the insect did not at first

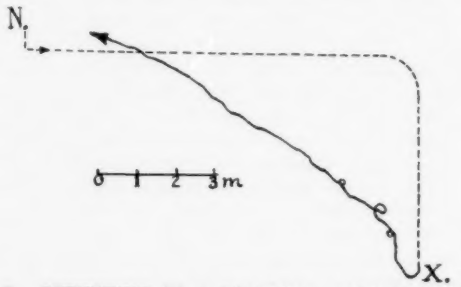


FIG. 7. RETURNING IN A DIAGONAL COURSE AFTER A FORCED DIGRESSION

take the diagonal, but reversed the second leg of the journey, but suddenly corrected its course, on reaching the sandy area, in the direction of the nest.

The question arises: Do ants possess an individual memory of locality, based upon successive associated engrams as has been proved to be true of bees? . . . Cornetz has denied the existence of such a genuine memory of locality, upon the ground that after being carried away from the nest ants are always completely disoriented. On the other hand I can offer in the support of this theory a whole series of observations of *Formica* in which these ants after being carried to a distance of 30 m. almost immediately reoriented themselves upon the shortest path towards the nest. It is true that I did not place my ants at some chance place selected at random, but at a location which had previously been frequently visited by the colony in question, so that it was to be expected that numerous ants would possess individual engrams of it. Naturally, however, I did not conduct the experiments until these visits had been entirely interrupted for some weeks and I also took every precaution to exclude every possibility of the presence of any odor trail to guide the insects.

I maintain, therefore, that we must attribute to these creatures a genuine—even if limited—memory of locality, based upon successive associated engrams of direction. . . .

But we have not yet exhausted all the means of orientation of which ants may possibly avail themselves, not at all! We still have an important group to be considered, *i. e.* the

[15] Ants, Bees, and Wasps, London, 1881.

kinesthetic signs of direction. . . . It has long been a disputed question as to whether insects are capable of feeling the force of gravity, and this has generally been denied in view of the extremely small weight of their bodies and the comparatively enormous muscular power which they are capable of exerting. It is my good fortune, however, to be able to offer proof that ants are not only capable of perceiving moderate elevations of the terrain by purely kinesthetic means, but that they are also capable in case of necessity, *i. e.* when all other signs of direction are excluded, of orienting themselves merely by this single, meagre kinesthetic engram.

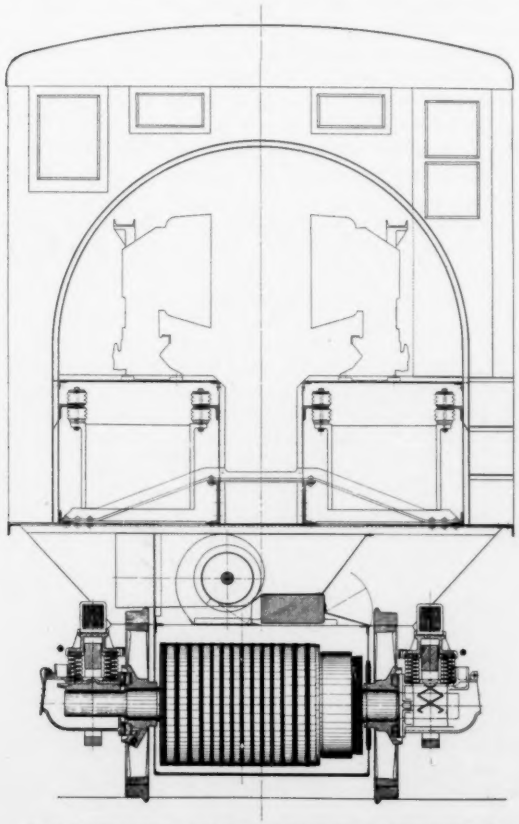
I proceeded as follows: To the edge of my large experimental table I attached an artificial nest containing a small colony of *F. rufa*. The exit tubes of the nest gave upon the top of the table. This table is so constructed that its top can be revolved in every plane of space, and all its axes of movement are exactly centered. In these experiments the table top was inclined at an angle of 20° to begin with in such a manner that the entrance to the nest was at the deepest position. The insects had to crawl upwards to reach the honey which was in a round bowl at the center of the table. Since the experiment was conducted in the dark tent with bipolar lighting described above orientation by light was excluded. I waited till an ant was seated at the feast of honey and then noiselessly changed the slope on the table top to the opposite direction, so that the nest was now above. Having finished his feast the insect started home, but was met by an unexpected puzzle! In all cases the ant first spent considerable time running back and forth undecidedly in both directions for a few centimeters each way, always returning to the honey. (It is interesting to note here the difference between these ants and the *Lasius* of the bridge experiment, which usually ran straight ahead in one direction—the *Formica* seemed on the other hand to be obviously conscious of a dilemma.) Finally, however, in every case the insect decided on a direction, and all of them *ran downwards without exception*, almost exactly to the deepest point, where they described narrowly limited curves for a long time, quite as if they were actually seeking the disappeared entrance to the nest!

Thus they had actually accomplished a virtual orientation by means of gravity! I must forego the citing of many interesting data bearing upon this complex theme. I trust, however, that I have convinced my audience that the distance orientation of ants is an uncommonly complicated phycho-physiological process. . . . Thus comparative psychology has here become an exact science—the comparative physiology of the individual Mnemo.

A Gearless Electric Locomotive

Details of the 3,000-Volt D.-C. Locomotive of the Chicago, Milwaukee and St. Paul Railway

IN the SCIENTIFIC AMERICAN of December 6, 1919, there appeared a narticle on an interesting "tug of war" between a giant electric locomotive and two steam locomotives. Rather it was a push of war for had a pulling test been staged the draw bars of the locomotives could not have stood the strain. In the test the electric locomotive came out victorious even though the steam locomotives were given a head start so as to enable them to attain their maximum horsepower. When the current was turned on the electric unit gradually slowed down the steam locomotives and then pushed them backward with accelerating velocity.



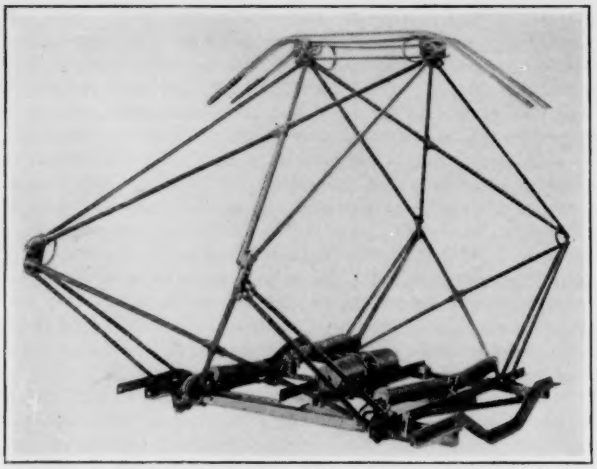
END ELEVATION OF THE GEARLESS LOCOMOTIVE

The big electric locomotive was one of a set of 3,000 volt direct current locomotives that are now being placed for passenger service on the Othello-Seattle-Tacoma electric zone of the Chicago, Milwaukee & St. Paul Railway.

The original electrification from Harlowton to Avery, 440 miles, has now been operating for a number of years under the extremely bad weather conditions of the Rockies and Bitter Root Mountains and, as a result of its unqualified success, the same system will now be used to meet the severe grades and snow conditions of the Cascade Range. The entire equipment for the original electrification was manufactured by the General Electric Company including substations and locomotives. The motive power consisted of 42 locomotives for freight and passenger service and four switchers. Of this original equipment, the freight and passenger locomotives were practically the same and differed from each other only in the gear ratio between motors and driving axles.

The new locomotives are an entirely different design, built distinctively for passenger service and possess some very interesting mechanical and electrical features. They will be used on the new Cascade electrification strictly for passenger service and the present passenger engines will be adapted for freight service by changing the gear ratio. The locomotives are of the bi-polar gearless type, with motor armatures mounted directly on the driving axles. In this fundamental feature, they follow the design of the gearless locomotives in use on the New York Terminal of the New York Central Railroad, which have given remarkable operating results during the past ten years. The chief advantage of this method of construction is the great simplicity of mechanical design which eliminates all gears, armature and suspension bearings, jack-shafts, side-rods or other transmitting devices. The remarkably low cost of maintenance of the New York Central locomotives over the entire period is attributed largely to the gearless type of construction.

The new Chicago, Milwaukee & St. Paul locomotives weigh 265 tons with 229 tons on drivers. They have fourteen axles.



TYPE OF PANTAGRAPH USED ON THE NEW GEARLESS LOCOMOTIVE

twelve of which are driving and two guiding axles. The weight of the armature and wheels is the only dead weight on the track and this is approximately 9,500 pounds per axle. The total weight on drivers (458,000 pounds) is 86 per cent of the weight of the locomotive but, being distributed among twelve axles, results in a weight of only 38,166 pounds per axle.

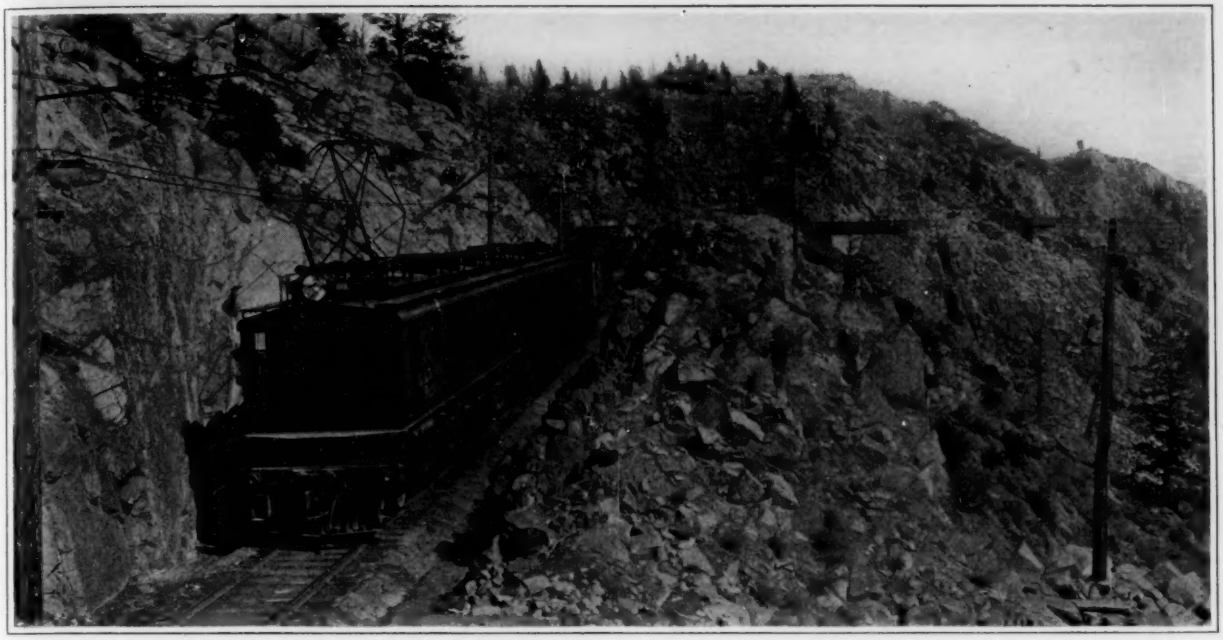
One of the most interesting and important features of the locomotive is the design of the leading and trailing trucks and the method of suspension of the cab weight upon them. The successive trucks are coupled together in such a way as to deadbeat or break up any lateral oscillations which may be caused by inequalities of the track. The weight of the main cab is so supported on the front and rear trucks that any lateral thrust or kick of the leading or trailing wheel against the track is cushioned by the movement of the main cab, which increases the weight bearing down on the wheels at the point where the thrust occurs, and automatically reacts to prevent any distortion of the track. The result of this design is such as to give riding qualities at high speeds which have probably never been attained before in a double-ended locomotive. Exhaustive tests on the General Electric Company's test tracks at Erie, Pa., have demonstrated the remarkable riding qualities of the new locomotive at speeds as high as 65 miles per hour which is the limit of speed on the length of test track available. These tests also indicate that the locomotive will operate at much higher speeds with equal success.

The locomotive is designed for handling in normal service a 12-car train weighing 960 tons trailing against a grade of 2 per cent at 25 m.p.h. This performance requires 56,500 pounds tractive effort which is equivalent to a coefficient of adhesion of 12.3 per cent of the weight upon the driving axles. The wide margin thus provided between the operating tractive coefficient and the slipping point of the wheels, as well as the ample capacity of the motors, will allow this locomotive to haul trains with as many as fourteen cars in emergencies. For continuous operation, the locomotive is designed to operate at 42,000 pounds tractive effort at a speed of 27 m.p.h.

The total weight supported on driving axles is practically the same as that on the present geared passenger locomotives, weighing a total of 300 tons. The table below gives the principal dimensions, weights and capacity of the gearless locomotive:

Length inside knuckles	76 ft. 0 in.
Length over cab	68 ft. 0 in.
Total wheel base	67 ft. 0 in.
Rigid wheel base	13 ft. 11 in.
Diameter driving wheels	44 in.
Diameter guiding wheels	36 in.
Weight electrical equipment	235,000 lb.
Weight mechanical equipment	295,000 lb.
Weight complete locomotive	530,000 lb.
Weight on drivers	458,000 lb.
Weight on guiding axle	36,000 lb.
Weight on each driving axle	38,166 lb.
Number of motors	12
One hour rating	3240 h.p.
Continuous rating	2760 h.p.
Tractive effort—1 hour rating	46,000 lb.
Tractive effort—continuous rating	42,000 lb.
Tractive effort—2 per cent ruling grade with 960-ton train	56,500 lb.
Coefficient of adhesion ruling grade	12.3 per cent
Starting tractive effort—25 per cent coefficient of adhesion	115,000 lb.
Rate of acceleration starting 2 per cent ruling grade	0.48 m.p.h.p.s.

THE 3000-VOLT D.-C. GEARLESS PASSENGER LOCOMOTIVE, WEIGHT 265 TONS



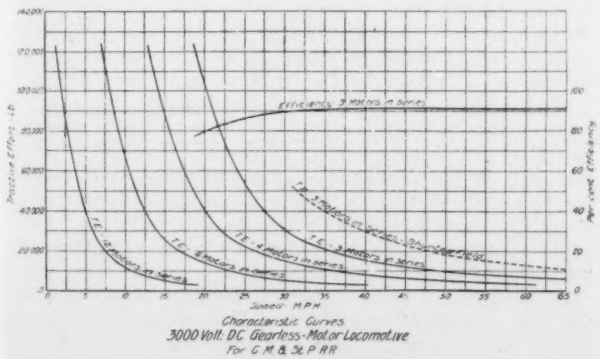
A WEST-BOUND FREIGHT TRAIN, NEAR GRACE, ON A 2% GRADE—55 CARS, WEIGHT 1,450 TONS

The control equipment for the new locomotive is similar in most respects to that used on the original locomotives which have now been operating nearly four years. Modifications were, of course, necessary to comply with the different arrangement of motors. Advantage is taken of a new scheme of connections by means of which four of the main locomotive motors are utilized to furnish exciting current during regeneration, thus reducing the size of the motor-generator set used for control, accessories and train lighting. An appreciable reduction in the weight of control equipment is obtained, at the same time providing for effective regenerative electric braking on the down grades. The motor-generator set furnishes control current for operating the contractors and for charging an 80-volt storage battery which supplies lights and power for the accessory apparatus. The battery is, in general, similar to those used on the passenger coaches. The master controller is constructed in three sections arranged for both motoring and regenerating, all of the cylinders being suitably interlocked to prevent incorrect manipulation.

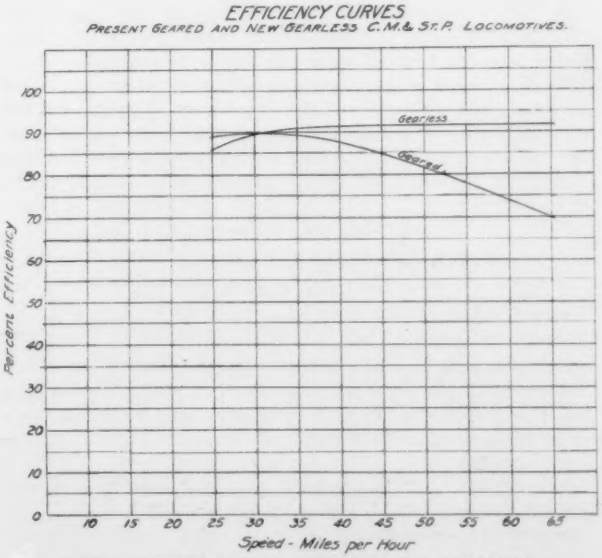
The motor is bipolar, two fields being supported upon the truck springs with full freedom for vertical play of the armature between the pole faces. On page 57 is shown an outline of the locomotive and one of the motors in section indicating the location of the armatures and the magnetic section. For full speed operation, the twelve motors are connected three in series with 1,000 volts per commutator. Control connections are also provided for operating four, six or twelve motors in series. Additional speed variation is obtained by tapping the motor fields in all combinations. Cooling air for each pair of motors is supplied by a small motor-driven blower. This arrangement avoids the heavy duct losses encountered with a single large blower.

As may be seen from the curves herewith, the gearless locomotive shows a much better efficiency at high speeds than the geared type owing to the elimination of the gear drive. In passenger service, where there are long stretches of level track and stopping points are comparatively few, a much higher efficiency is obtained in all-day service. These curves show an efficiency at 50 miles per hour approximately 10 per cent higher than the geared type of locomotive.

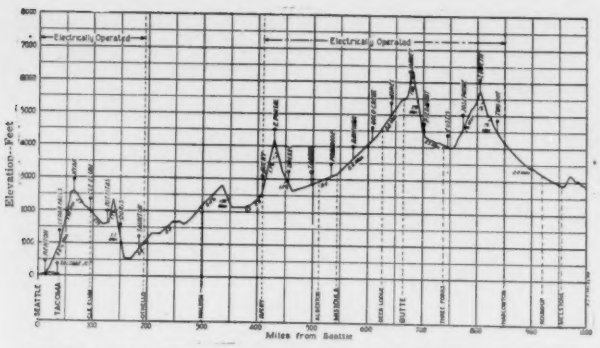
The 3,000-volt contactors and grid resistors are mounted in the curved end cab at each end of the locomotive. In one of these cabs there is also located the 3,000-volt d-c. air compressor and storage battery. In the other is located a small motor-


Efficiency 3 Motors in Series
T.E. 3 Motors in Series
T.E. 6 Motors in Series
T.E. 12 Motors in Series
Speed - M.P.H.
Characteristic Curves
3000 Volt D.C. Gearless-Motor Locomotive
For C.M. & St.P. RR.

CHARACTERISTIC CURVES OF THE GEARLESS LOCOMOTIVES



EFFICIENCY CURVES ON GEARED AND GEARLESS LOCOMOTIVES



PROFILE OF THE ELECTRIFIED DIVISION OF THE CHICAGO MILWAUKEE AND ST. PAUL RY. FROM HARLOWTON TO THE COAST

generator set and the high speed circuit breaker. The operating cabs contain the master controller, indicating instruments, and a small air compressor (in No. 2 cab) operated from the battery circuit with sufficient capacity for raising the pantograph when first putting the locomotive in operation. Near the controller are the usual air brake handles for standard braking equipment.

The center cab is occupied by the oil-fired steam boiler for heating passenger trains with accessories including tanks for oil and water, circulating pumps and a motor-driven blower for furnishing forced draft. A slider pantograph, similar in construction to those now in use, is mounted on each of the operating cabs. This pantograph has two sliding contacts, giving a total of four points per slider with the double trolley. The pantograph and flexible twin trolley construction enable the locomotives to collect currents as high as 2,000 amperes at speeds up to 60 miles per hour without noticeable arcing at the contact points. The second pantograph is held in reserve as a spare. Sand boxes, with pipes leading to each pair of driving wheels, are located directly beneath the pantograph outside the operating cab.

The diagram above gives a profile from Seattle to a point about 1,000 miles east, including the Cascade electrification, the Harlowton-Avery electrification and the intervening 220 miles. The new locomotives will operate over the section between Othello, Seattle and Tacoma, including 17 miles of 2.2 per cent grade from the Columbia River west and 19 miles of 1.7 per cent grade between Cedar Falls and the summit of the Cascades. The traffic over this division consists of the heavy main line transcontinental passenger trains "Olympian" and "Columbian," carrying from 8 to 12 steel passenger coaches which will be handled over the maximum grades without helpers. Freight pushers are already in operation on the 2.2 per cent grade, using two of the locomotives from the original electrification. It is expected that electrical operation during the present winter will assist in overcoming many of the delays which are commonly met with during winter operation in this district.

CONCRETE FUEL OIL RESERVOIRS.*

By H. B. ANDREWS.

UNTIL recently steel containers have been used generally for fuel oil. Concrete had not been considered as a suitable material due to lack of evidence and knowledge of its possibilities. But the practical elimination of steel plates during the war forced the use of a substitute, and reinforced concrete has proved to be satisfactory in many ways, if intelligently handled.

For example: It is necessary to install most fuel oil reservoirs underground, but steel tanks rust if not protected. Concrete can be designed better to resist exterior stresses, as hydrostatic or earth pressures. It has the dead weight better to resist upward hydrostatic pressure in soils which often are filled with water. It does not attract lightning like steel, nor if properly constructed is it affected by electrolysis. It is a non-conductor of heat and cold, thus retarding evaporation of oil in summer, and also retarding the lowering of temperature of the oil in winter—an advantage in pumping. In case of a conflagration the oil is much safer in a concrete container than in steel.

But as previously stated, oil reservoirs of concrete must be designed correctly, the concrete proportioned correctly and mixed and placed correctly in order to get satisfactory results. And by satisfactory results it is meant that there shall be no leakage or seepage when built or thereafter to cause fire hazards or financial loss.

When these necessities have been provided for, reinforced concrete reservoirs will contain fuel oil of a consistency up to 40° B., and practically all fuel oils are below this, the Mexican oils having a specific gravity as low as 16° B. For the lighter oils, including kerosene, gasoline or benzine, some provision should be made for a lining of special material, and the writer understands that the U. S. Shipping Board has been making some extensive experiments along this line.

The design and the location of a fuel oil reservoir may be considered from various standpoints.

(1) Location. The reservoir should be located a safe distance from inflammable structures as far as possible consistent with pumping requirements, covered with at least 16 inches of earth, if near buildings, to decrease fire hazards and also to minimize oil evaporation. If distant from buildings it should be at least half underground, and if possible, the excavated material should be used in banking up around it.

(2) Size. The reservoir should be limited in size for two reasons: First, the necessity of not exceeding a day's working limit in operation of pouring concrete so that joints between operations may be eliminated and secondly, so that in case of an accident or fire in any reservoir, that too much oil in storage will not be involved. This size limit should not be over 300,000 gallons under most conditions, and the majority of contractors have not the facilities to construct properly a reservoir of this capacity.

(3) Shape. The reservoir should be circular in shape, the better and more directly to take care of involved stresses and to avert danger of tensile or temperature cracks.

(4) It should be so proportioned and designed as to limit the number of pouring operations of concrete, so as to avoid joints between these operations.

(5) Care should be taken to provide for all exterior stresses, such as hydrostatic pressure from ground water, earth pressure on walls, and roof if reservoir is buried, and also to avoid as far as possible concentration of loads on walls or footings. Where joints are absolutely necessary to so protect these joints that there will be no leakage through them.

Regarding hydrostatic pressure, while engineers have found from tests that this pressure in soils is only about 50 per cent of the full head of water, it is not safe to design for stresses less than the full head, as any deflection in the concrete admitting a film of water between the earth and the concrete will produce the full hydrostatic pressure.

(6) To so design the reservoir, piping and vents as to comply with municipal regulations and insurance requirements.

(7) To protect temporarily or permanently concrete surfaces so that oil will not come into immediate contact with them if concrete is less than six weeks old.

(8) To so design the false work for holding concrete temporarily in place that it will not fail or be distorted while placing concrete. It is especially necessary to provide for the firm holding of wall forms, as the pressure of several feet of concrete poured quickly as a monolith, is intense, and any give of the forms after the concrete has obtained its initial set breaks up the crystals already formed, allows ex-

*From *Oil News*.

pansion of the concrete mass, with resultant porosity and loss of strength.

(9) To design the concrete so that it will resist all exterior stresses to which it is subjected and so that it will be oil-proof. And one of the principal features of this design is to make the walls of circular reservoirs in tension, sufficiently thick so that the ultimate strength of the concrete in tension will not be exceeded. It is not meant, of course, to leave out the steel reinforcement so that the stress will theoretically be borne by the concrete, but, nevertheless it will actually be borne by it unless some unforeseen weakening of the concrete should throw it upon the steel.

An extended investigation by the writer on high circular concrete standpipes for water showed that if the concrete in the wall was stressed beyond its elastic limit or ultimate strength, which is practically identical, vertical hair cracks will appear of sufficient width to admit water into the body of the concrete.

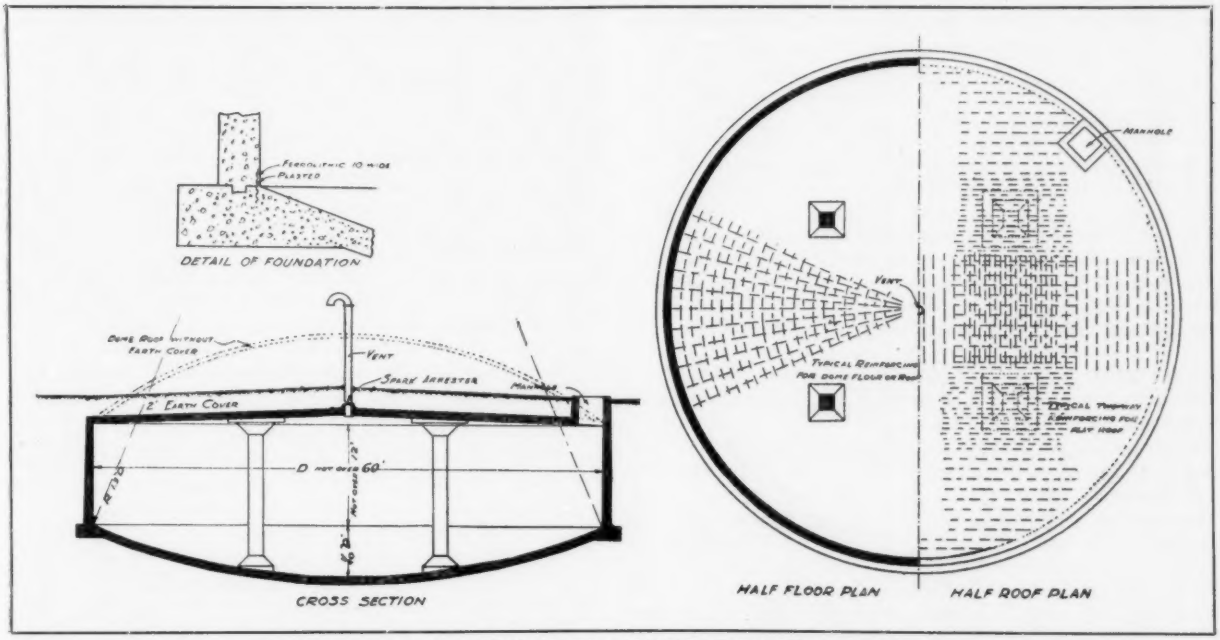
the Joint Committee on Concrete, Plain and Reinforced, should be followed.

All reinforcing rods in concrete exposed to oil should be of a deformed section for better bonding value.

COMPETENT ENGINEERS ARE NECESSARY.

To carry out these requirements necessitates the employment of competent engineers, experienced in the work, to make the design and specifications and to superintend construction.

The concrete should be no leaner than a mix composed of 1 part of cement, 1½ parts of sand and 3 parts broken stone or gravel. To this mix should be added a "densifier." Hydrated lime has been found economical and satisfactory for this purpose, using 10 pounds of dry lime to each bag of cement. The stone must be hard and clean, trap rock, granite or gravel being the best material. The sand must be free from any deleterious matter, and should be well graded. Cement should be of an established quality.



PLANS OF A TYPICAL REINFORCED CONCRETE FUEL OIL RESERVOIR

This ultimate tensile strength in a 1:1½:3 concrete from tests made for the writer at the Watertown Arsenal was 203 pounds per square inch. Where the concrete is in large sectional areas and reinforced, this tensile strength probably will be somewhat higher.

If a stress not exceeding 150 pounds per square inch is allowed in tension there will be no danger of these vertical cracks appearing.

(10) To design the reinforcement so that it will take care of all interior and exterior stresses and with fittings to hold it rigidly in place while concrete is being poured. Steel in tension in walls should not be stressed over 10,000 pounds per square inch to conform with insurance companies' requirements.

Personally, the writer does not think that it is necessary to figure the stress as low as this, under usual conditions, having satisfactorily constructed many reservoirs using a stress of 14,000 pounds, but of course, the lower stress is an additional safeguard against inferior workmanship by inexperienced contractors and against any decrease in bond strength due to oil penetration of concrete. It is probably unwise to depart radically from insurance companies' recommendations.

For other parts of the reservoir the recommendations of

The concrete should be deposited continuously in concentric layers not over 12 inches deep in any one place.

No break in time of over 30 minutes is permissible in depositing concrete during any one operation, and if any delay occurs, the previous surface must be chopped up thoroughly with spades before the next layer of concrete is deposited.

The different operations in pouring are:

1. The pouring of floor and footings.
2. The pouring of entire wall.
3. The pouring of roof.

In small reservoirs the wall forms may be supported so that the footings, floor and wall may be poured in one continuous operation.

An approved joint or dam must be made between the floor and the wall.

When the materials are obtained they should be mixed by a plant of sufficient size and power to carry out each separate pre-arranged operation without danger of delay during the process.

The materials should be mixed at least 2 minutes in the mixer, using just enough water to obtain a plastic mix without excess water coming to the surface after concrete is deposited, and a measuring tank should be used so that the amount of water may be kept uniform.

A Vacuum Pan for Laboratory and Experimental Use

Directions for the Construction of the Apparatus

By F. Alex. McDermott, Mellon Institute, Pittsburgh, Pa.

IT frequently happens in experimental work that it is desirable to have some small apparatus for the purpose of evaporation of a liquid in a vacuum, which will have characteristics rather nearer those of the large commercial machines than can be obtained with a simple round bottom flask. The apparatus which is here described was designed to meet this need, and has proven very satisfactory for a considerable number of purposes. In copper and brass it can be made easily by anyone who can do soldering and has the use of a small screw-cutting lathe, or a simple lathe and a pipe-threading device.

The original apparatus, shown in the photograph (Fig. 4) was constructed of aluminum, for use on acid food-products

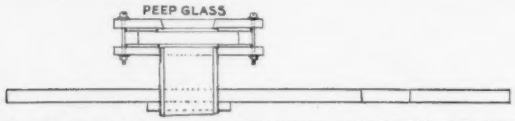


FIG. 1. SECTION OF LID SHOWING MOUNTING OF PEEP GLASS

such as fruit juices, where copper or iron could not be used on account of the attack on the metal and consequent deterioration of the flavor of the product. In this case, the body of the pan consisted of a cylinder of aluminum, 7½ inches in internal diameter, with walls 3/16 inch thick, closed at one end by a flat bottom ¼ inch thick, and provided at the top with a flange 3/16 inch thick and 1 inch wide, making the total diameter of the top 10 inches. The construction of an aluminum body for such a vacuum pan, owing to the difficulties in the way of working aluminum with the facilities ordinarily available to the amateur, is best done by those who are constantly working with the metal, and in the case of the original apparatus, was done by an outside untensils factory. The method employed appears to have been as follows: a sheet of metal 3/16 inch thick was bent into the form of a cylinder 8 inches in outside diameter; a piece of metal ¼ inch thick was then spun out to form the bottom and a portion of the side, of the same outside diameter as the cylinder; the seam in the cylinder was then welded together, and the spun out bottom welded on, making a solid, one-piece body, the flange being welded on around the open end. The body of the original aluminum pan is 13 inches deep inside, of which depth, the welded cylinder represents about 10½ inches.

For the amateur, copper construction is much easier, and for use with this pan a small copper body was also constructed as follows: A piece of sheet copper, tinned on one side, and about 1/32 inch thick, was cut 6⅜ inches wide and 25¼ inches long; this was rolled into a cylinder eight inches in diameter, tinned side in, and a crimped joint made at the seam; a circular disk of the same copper, 6¼ inches in diameter was then taken, and one-eighth inch of the edge hammered over to form a flange at a right angle all the way round, the tinning being on the side opposite to that over which the edge had been turned. This disk was then slipped into one end of the copper cylinder, as shown in the sketch (Fig. 2) until somewhat more than one-eight of an inch of the cylinder was exposed below the end of the turned-over edge of the disk; this projecting edge of the cylinder was then turned in over the edge of the disk, and crimped down firmly in place. Of course a dished head of thicker metal, with a short cylindrical extension to slip over the cylinder, could be used in place of the flat head to some advantage. In either case the upper end of cylinder is fitted with a brass ring ⅛ inch thick, one inch wide, and 10 inches in outside diameter, which fits snugly around the cylinder; all joints are then liberally soldered. If it is desired that only the tinned surface be exposed to the liquid to be treated in the pan, this soldering should all be done on the outside of the pan; if the pan is to be silver plated inside, plain copper may be used, and the soldering put on the inside. If a pan more than 6 inches deep is desired it will be necessary to use much heavier copper, or to reinforce the body by soldering in a ring of ⅛ inch brass, fitting just inside of the cylinder, at each four to five inches of the total height—i. e., one such ring in a pan 10 inches deep, two in pan 15 inches deep, etc.

In the pan as constructed all heating arrangements, inlets and outlets, etc., are provided through the cover. This was done to obviate the necessity for holes through the body, which might be difficult to make tight. The cover thus becomes an important piece of the apparatus. It consists of a disk of the metal used (aluminum for the aluminum pan, brass, plated if desired, for the copper pan, etc.), ⅛ or 3/16 inch thick, and 10 inches in diameter. In this cover are drilled seven holes, as shown in the drawing (Fig. 3); four of these are ¾ inch in diameter, tapering very slightly to the under side of the disk, and are to receive rubber stoppers bearing the steam inlet and outlet tubes for the heating coil, a thermometer, and a separatory funnel or other device for admitting liquid to the interior of the pan. The other three holes are threaded to receive one inch standard pipe, and are to provide for the vapor outlet and peep glasses. In the original pan all of the latter were made up from sheet aluminum of standard thickness, or of standard pipe fittings, which may

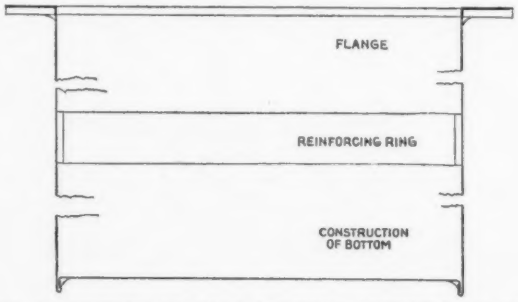


FIG. 2. SECTION OF BODY SHOWING ASSEMBLY OF DISK AND CYLINDER

be obtained in aluminum. The peep glasses consisted of a circle of plate glass two inches in diameter clamped against washers of 1/16 inch red rubber packing, ½ inch wide, between circles of the metal used, 3/16 inch thick and 3¾ inch diameter; using brass, these circles could be made somewhat narrower, 3½ inches diameter, at least. The central hole in each was bored one inch in diameter, and the upper circle of the peep-glass was reamed out to a taper to 1¼ inches at the top; the hole in the lower circle being tapped for one inch standard pipe thread. The two pieces, with the included washers and glass, are held together by six bolts with nuts and washers, spaced evenly, and with centers ½ inch from the edge of the circle.

The peep glasses (Fig. 1) are mounted on short lengths of standard one-inch pipe, projecting about ⅜ inch on the under side of the cover, and a hexagonal nut, made from a piece of sheet aluminum or other metal used, is screwed up tightly against the cover on this projecting nipple to reduce the possibility of leakage in of air when exhausted. A simi-

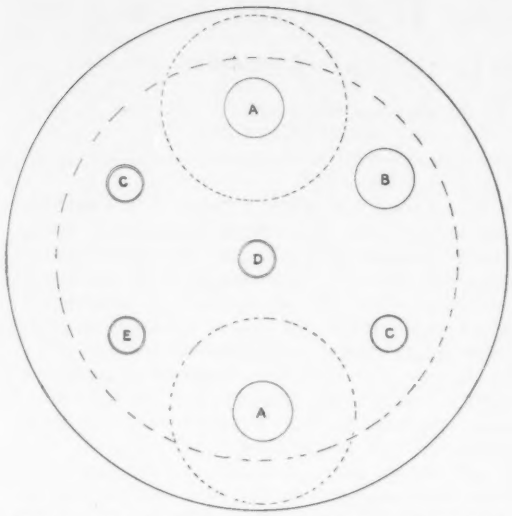


FIG. 3. HOLES IN HE COVER OF THE VACUUM PAN

lar lock nut is used on the vapor outlet pipe. By placing a shaded electric light over one of these peep glasses, the condition of the contents of the pan may readily be observed through the other.

The vapor outlet is arranged to have ample cross section, and to provide for connection by means of a rubber stopper to a surface condenser; a vacuum break is also provided in this connection in the original apparatus. The vapor outlet consists of a vertical piece of one-inch pipe, about 6 inches long, bearing at its upper end a standard T, with the side outlet facing outward at right angles to the axis of the body of the pan. Into the upper, open end of this T is conencted the vacuum break—an ordinary stop-cock, connected by standard threaded pieces, and preferably so arranged that any vapor which may condense in it when closed will not run back into the contents of the pan. To the side outlet is connected a short piece of the same pipe, then a 45° elbow, and then another piece of the same pipe, the free end of which is slightly tapered to take a large rubber stopper. A mercury or dial vacuum gage may be connected at the vacuum break.

As a condenser the original apparatus is used in connection with a multitubular condenser consisting of seven 3/16-inch copper tubes, 15 inches long, surrounded by a water jacket; this condenser has given very good results with this pan. Single tube condensers of either metal or glass are usually insufficient to condense more than a portion of the vapor of the liquid boiling under vacuum. The outgoing end of the condenser is connected by means of a rubber stopper into a 2- or 4-liter filter flask in which the condensate collects. Direct connection to a wet type vacuum pump, or to water jet vacuum pumps, is of course allowable when the condensate is not to be saved for study.

The interior heating element is a simple flat helix of tubing, ¼ inch inside diameter, having preferably a moderately thick wall, say 1/32 inch. The flat coil is so placed as to be just above the bottom of the pan inside, and it is held in place by the vertical inlet and outlet tubes extending through the cover. It would be of course be possible to pass these through some type of stuffing box, but it is the writer's experience that it is well to have this heating element not too firmly held in place, and the rubber stopper arrangement has given satisfaction. Of course, also, the steam coil may be omitted, and the pan heated by an external steam, hot water or oil bath; but this method is less efficient, although desirable if the substance is to be evaporated to dryness. When using the internal steam coil it has been the writer's practice to deliver the exhaust steam and condensed water into a loose jacket surrounding the bottom of the pan, and provided with an overflow, thus reducing loss of heat from the exterior of the pan.

To operate the pan it is set up and connected to the vacuum pump, with or without the condenser, as preferred for the work at hand, and tested empty to ascertain how high a vacuum it will maintain with the pump running. Some small leakage always occurs, but unless this is very bad it will influence the working vacuum but little when a pump of sufficient power is used. Much depends upon the evenness of the surfaces of the body flange and the cover, and the nature of the gasket or washer used. For the latter a good quality of red rubber packing ⅛ inch thick has been found best. When the operation is satisfactory from this standpoint, the liquid to be evaporated is admitted through the separatory funnel, preferably not more than a quart being admitted at first, and further additions made at the rate of a pint at a time as the collection of the condensate indicates. As much as two quarts may be used initially in the 13-inch deep pan, but if the liquid foams severely this amount will usually cause foaming over into the condenser. Various forms of foam traps have been devised, but ordinarily none are quite as satisfactory as not starting with too much liquid.

When the desired amount of evaporation has taken place the apparatus is disconnected from the vacuum, being careful to open the vacuum break first, especially if a water-jet pump is used, when there is no stop-cock between the pump and the pan. The cover, which has been held on by means of small clamps, when the vacuum was being established, is removed, and as much of the liquid as possible allowed to drain from the steam coil. The whole pan is then inverted, and the contents allowed to drain into a receiving vessel.

PROPOSED 220,000-VOLT TRANSMISSION SYSTEM.

THE proposed "California Transmission Bus" is an overhead line to connect the power systems of Pitt River, Feather River, Big Creek River and Colorado River. The line will have a total length of 1,100 miles and will handle 1,500,000 kw. at a working pressure of 220,000 volts.

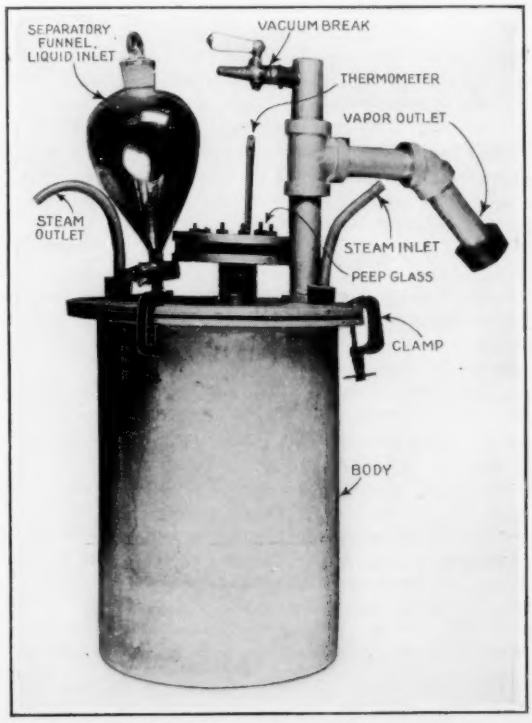


FIG. 4. THE FINISHED VACUUM PAN READY FOR USE

Danger of Automobile Exhaust Gas

Need of Investigating Conditions in Vehicular Tunnels

By Van. H. Manning, Director, U. S. Bureau of Mines

THE rapidly increasing use of motor vehicles and trucks in the United States is creating an entirely new problem in the proper ventilation of tunnels, subways and other confined places where such machines must pass through. The traffic congestion in our larger cities, due to motor trucks and automobiles, is becoming so great that subways or double-decked streets will soon be required to relieve the situation; indeed, Chicago is now double-decking Michigan Boulevard along the lake front in the downtown district. The upper street level is to be used by passenger cars and the lower level by heavy trucks. The danger of poisoning from the automobile exhaust gases in the confined lower level is serious, probably more so than generally realized.

However, a much more dangerous condition may arise in long street and vehicular tunnels which must depend entirely on artificial ventilation for the removal of deleterious gases. Tunnels of this character are now under consideration in a number of different places in the United States, and the Bureau of Mines has received several requests for information on the physiological effect of automobile exhaust gases and on the amount of deleterious gases that are emitted from automobiles and trucks under various conditions of use. Such information is required by engineers who are charged with designing the ventilating equipment for tunnels. Engineers are agreed that present information is inadequate and unless reliable data is provided by further investigations the public will suffer either acute physical discomfort and illness from breathing polluted atmospheres due to insufficient ventilation. or the public purse will have to bear the fixed charges of excessive overventilation.

NATIONAL ASPECT OF PROBLEM.

It is just and proper that the Federal Government should investigate this problem rather than local communities or states. Tunnels are being considered in many parts of the United States. The largest one for which immediate information is wanted is the proposed vehicular tunnel between New York and New Jersey under the Hudson River. This tunnel will be 9,000 feet long and will have an estimated maximum number of 2,000 automobiles and trucks per hour passing through it during rush periods. The amount of poisonous gas given off by this long line of machines is almost beyond conception, certainly it cannot be guessed at. That this fact is fully appreciated by the New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission is shown in a letter from the chairman of the two commissions to the Secretary of the Interior asking the Bureau of Mines to conduct investigations on automobile exhaust gases with respect to tunnel ventilation.

The South Hills Tunnel at Pittsburgh, Pa., now being designed, will be a little over a mile in length and will be used by a great many passenger autos and trucks. Mr. Neeld, Chief Engineer, has consulted the bureau's experts on ventilation and has based his design largely on the fragmentary data provided in the Bureau of Mines investigations of "Gasoline Mine Locomotives in Relation to Health and Safety" (Bulletin 74). Vehicular tunnels are also being considered in Louisiana, California, under the Delaware River at Philadelphia, under the East River at New York and in Boston, Mass.

POISONOUS CHARACTER OF AUTOMOBILE EXHAUST GASES.

That the general public is beginning to appreciate, in a measure, the poisonous character of automobile exhaust is shown by the following clipping from the *Pittsburgh Sun* of November 30, 1919, under the caption of "Chemistry in Every Day Life," by "Crucible."

"Poisoning from Automobile Exhaust."—It is not uncommon to read about finding a man dead in his garage. When this happens the account goes on to state that the engine was running, and that the doors and windows were closed. The natural conclusion is that there must be a poisonous product generated by the engine, and that this product accumulated in the closed garage in sufficient quantities to cause death.

The experts of the Bureau of Mines[1] as well as various automobile engineers have investigated this problem and the cause of the poisoning and the conditions that produce the poison are pretty well understood.

The poison is a gas, carbon monoxide by name. It is the same thing that miners find after mine fires or explosions, and they call it "black damp." People who use coal gas have to watch out for leaks because of the presence of carbon monoxide in the gas.

Carbon monoxide has no color, taste, or smell. It has nothing to do with the cloud of smoke that pours out of the exhaust pipe of a car once in a while. There may be, and probably is, carbon monoxide in the smoke, but it isn't monoxide that you see.

Practically speaking it is impossible to run an automobile engine without producing carbon monoxide. In the course of this investigation tests were made where none was produced, but it was done by using a mixture so "lean" that the average engine will not start on it if cold, and very few carburetors are adjusted to use such a mixture at all. Furthermore, the difference between the production of a large amount of carbon monoxide and none at all is so slight that a carburetor if adjusted would not continue to deliver the mixture more than a few moments. An example will show this. A mixture containing 4.1 parts of gasoline vapor in 100 parts of mixture gave an exhaust on a 30 horse-power engine that contained 14 per cent of carbon monoxide, while with a mixture of 2.5 parts gasoline vapor in 100 no carbon monoxide was produced.

Further experiments along this line carried out on 13 different automobile engines with good mixtures and very rich mixtures showed in the first case amounts of carbon monoxide varying from 10 to 36 cubic feet of carbon monoxide produced each minute, while the results with rich mixtures gave from 135 to over 600 feet a minute.

Carbon monoxide is very poisonous. The presence of one part of the gas in 500 parts of air will cause a person to collapse within an hour, while larger amounts will shorten this time.

In order to see how soon the air in a garage might be affected by the running of an engine, samples of the air were collected while a 30-horse-power engine was operating. It was found that in less than 15 minutes a dangerous amount of gas had accumulated around the car.

It follows that an engine should never be run in a closed garage. Dangerous amounts of poisonous gas will be present in the air before there is time to do much repair work.

It is not much pleasure to work over a car on a cold winter day with the garage doors wide open, for no matter how much of a heating system there may be the building will soon get pretty chilly. It is possible to fix up a simple arrangement that will get around the discomfort of working practically out of doors, and at the same time be perfectly safe. A short length of hose one end of which is slipped over the exhaust pipe while the other end reaches out doors will do the trick

[1]Technical Paper 216, "Vitiation of Garage Air by Automobile Exhaust Gases," by G. A. Burrell and A. W. Gauger.

provided it is not necessary to open the cut out while the engine is running.

If you feel a dull, depressing sort of a headache with a faint spell or two after working over a car you have probably got too much carbon monoxide. Not enough to be really dangerous but a warning. If you feel very faint a doctor should be called in at once as after one has actually collapsed recovery is difficult.

EXHAUST GASES FROM GASOLINE ENGINES IN TUNNELS.

Although data which directly show the conditions which are to be encountered in long street tunnels are not available, some investigations on the composition of automobile and other gasoline engine exhausts have been made. Some of these deal with mines. This data may be used for showinng the possible conditions in the tunnel until experiments are made which exactly apply to the problem.

Chase[2] made experiments with twelve passenger cars and three trucks, all representing different types which were run over city streets under various conditions. Samples of the exhaust gases were secured and analyzed usually on nine different runs for each car.

A general summarizing of the results shows a maximum production of 6.8 per cent of carbon monoxide in the exhaust gases, an average of 2.1 per cent and minimum of zero per cent. While these figures are of some value, it is believed that more carbon monoxide is produced in the average car of today.

The cars tested were comparatively few in number, the carburetors were purposely put in good adjustment, and the grade of gasoline has changed since 1914, so it is doubtful if they represent the average for street traffic today. The low percentage of carbon monoxide found from the three trucks certainly does not show the range of carbon monoxide from trucks in general.

The Bureau of Mines has made experiments with mine locomotives run by gasoline engines with a view to safety from poisonous constituents in their exhaust gases in mines. The following extract from Bulletin 74[3] is of general interest in this connection:

"The process of combustion in the cylinder is affected by several variables: some are under the control of the motorman whereas others are not. Owing to the variety of variable factors it is difficult to duplicate conditions exactly, either in practice or in the laboratory, in order to study the effect of a single variable. The operator of a gasoline locomotive can readily observe only two variables—namely, the speed of the engine and the ability of the locomotive to pull its full load. From these he infers the existence of any wrong condition and then makes various adjustments to right it. These adjustments may result in producing exhaust gases of widely varying character and still enable the engine to pull the load. If the adjustments are not skilfully made the engine may lack both speed and power and the exhaust gases again be changed in character. Some combination of speed, power, and poor adjustment will produce the maximum quantity of noxious gases. This combination exists when the engine is using the maximum quantity of gasoline on which it can pull the full load at the full speed. Greater percentages of noxious gas can be made when throttling the mixture to suit conditions of half speed and half load, but the total quantity of noxious gases produced is less because of the reduced speed. The most dangerous condition of a locomotive as a producer of noxious gases, therefore, is when the engine is working at full speed and with full load and is using the most instead of the least gasoline that it can use to maintain the speed.

"The exhaust gases consist of the products of both perfect and imperfect combustion of the fuel. Analysis shows them to be a mixture of carbon dioxide, carbon monoxide, oxygen, nitrogen, hydrogen, and water vapor, and also, it is believed, small but negligible quantities of gasoline vapors."

The paper also gives a table which presents probably the best data now available for use in safeguarding persons in street tunnels.

The amount of carbon monoxide produced by the smaller mine locomotives may be comparable to that produced by trucks, but not necessarily so.

In other experiments the Bureau[4] studied the vitiation of garage atmosphere by automobile exhausts. A 30-horse-power, four-cylinder engine of an automobile truck was allowed to run in a closed garage of about 5,000 cubic feet capacity. Samples of air from different parts of the garage were secured at different times and analyzed. In the comments on the results this statement is made:

"It is interesting to note that at the back of the automobile, at B, there was a slightly higher percentage of carbon monoxide in the sample taken near the floor than in the sample taken six feet from the floor. This is not surprising in view of the fact that the exhaust gases are expelled about a foot above the floor. Dangerous amounts of carbon monoxide were present in the farthermost parts of the garage after the engine had run 20 to 30 minutes, whereas near the machine the air was extremely unsafe when the engine had run about 15 minutes."

The fragmentary information cited above will enable engineers to draw enough approximation of the ventilation needs of city street tunnels but it is still quite insufficient for the needs of the case. If one considers that the well-being of thousands of people daily is to be carefully safeguarded, many of whom are constitutionally able to withstand only minute quantities of the gases which pollute tunnel air, the need of precise information is apparent.

INJURIOUS CASES OTHER THAN CARBON MONOXIDE.

In the foregoing matter carbon monoxide has been assumed to be the only harmful constituent of tunnel air. That other gases or vapors may be present is well shown in the extract below from a letter dated November 10, 1919, received by the Bureau from E. W. Roberts, Editor of *The Gas Engine*, published at Cincinnati, Ohio. The letter is also typical of other requests for information on the subject:

"It is not generally known exactly what the physiological properties of gasoline vapors are. From experiments that the writer has made, he has found that petroleum vapor has anaesthetic properties. Reference is made to this subject on page 647 of Brants 'Petroleum and Its Products.' As the bulk of gasoline vapor at ordinary temperatures consists of pentane, we believe that the properties of this material are those to be considered.

"Experiments have been made on animals, the results of which are confirmed by a number of experiences of persons who have worked in an atmosphere of gasoline vapor and show that pentane vapor when mixed with oxygen produces a stupor. An odd phase of this subject is that persons have worked in an atmosphere heavy with gasoline vapor and experienced no ill effect until after they have passed to an atmosphere entirely free from the vapor.

"In order to explain this matter more definitely, I will cite two instances:

"The owner of a small private mine near New Philadelphia, Ohio, some years ago was working with a plumber in a room off the main air way repairing a pump driven by a gasoline engine. The carburetor of the engine was flooding and they had difficulty in starting it. It was asserted afterward that they were working in this atmosphere heavy with gasoline, for approximately one hour. On leaving the room

[2]Chase, H., Exhaust gas analysis for economy: *The Automobile*, Vol. 30, 1914, pp. 395-9, 422-6, 469.

[3]Hood, O. P., Kudlich, R. H., Gasoline mine locomotives in relation to safety and health, with a chapter on methods of analyzing exhaust gases: *Bureau of Mines*, Bulletin 74, 1915, p. 83.

[4]Burrell, G. A., and Gauger, A. W., Vitiation of garage air by automobile exhaust gases: *Bureau of Mines*, Technical Paper, 216, 1919, p. 12.

and going to the main air way both the plumber and the mine owner collapsed a short distance from the opening into the room. The plumber fell with his face in a pool of water and drowned. The mine owner was later discovered by a rescue party and revived.

"A similar case is one which occurred at Chicago some years ago. A man was working in his garage, with closed doors, adjusting a carburetor which was flooding. He was called to the telephone and collapsed a short distance from the garage after getting out in the open air.

"Our reason for calling your attention to the peculiarity of gasoline vapors, is that we believe that it might be worth while investigating, particularly as these effects are almost invariably attributed to carbon monoxide poisoning.

"Should you find this matter to be of sufficient interest to follow up in the experimental way, the writer will be very glad to learn the results of your tests."

WHAT SHALL BE THE MAXIMUM ALLOWABLE PERCENTAGE OF CARBON MONOXIDE IN TUNNELS?

In order to render tunnels safe for those using them sufficient air must be introduced into the tunnel to so dilute the exhaust gases that the percentage of carbon monoxide is reduced to a point where it becomes harmless. After sufficient experiments have been made to determine how much carbon monoxide is given off by various automobiles and trucks, the next question that arises is the maximum allowable per cent of carbon monoxide that will do no harm. Is it 0.1 per cent or 0.01 per cent or somewhere between these limits? Physiological authorities differ in their opinion over this range. This divergence appears to be due to a lack of sufficient experiments. Dr. Haldane, the noted English authority, recommended 0.01 per cent carbon monoxide as the safe limit for the atmosphere in the Metropolitan Tunnel in England. Other authorities think that the concentration may be increased to nearly 0.1 per cent for short periods of time.

Another very important phase of this problem is the effect of carbon monoxide and exhaust gases on women, children and persons in delicate health. Individuals that are anemic or affected with heart disease are undoubtedly affected by smaller percentages of deleterious gases than normal individuals. Most of the work heretofore done on carbon monoxide poisoning has been with reference to workmen in mines and in the industries. The data thus obtained is not directly applicable to tunnel conditions, where all sorts of individuals, and a less robust average must be considered.

Large Electric Steel Smelting Furnaces*

Some Interesting Phenomena

By Victor Stobie

LARGE electric arc steel-melting furnaces are preferable for ingot making, but smaller furnaces have a very large field in foundry work. Observations will be confined mainly to large plant and to some interesting phenomena on all furnaces.

WIRING DIAGRAMS AND SHAPES OF FURNACES.

The wriing diagrams (Figs. 1, 2 and 3) give the best connections for three sizes of furnaces. Fig. 1 is for furnaces up to 6 tons' capacity, two-phase current, each phase maintained entirely separate from the other, with one end of each phase connected to separate electrodes above the bath, and the other end of each phase connected to separate electrodes embedded in the hearth of the furnace at opposite ends of the furnace to their relative top electrodes. This arrangement gives the requisite bottom heating for small furnaces and leads to crossing of the currents in the direction of flow through the bath. Fig. 2 is for furnaces from 6 tons up to 24 tons' capacity, two-phase current, each phase maintained entirely separate from the other, with each end of each phase terminating in an electrode above the bath. Bottom electrodes, while essential in small furnaces, are undesirable in large furnaces. Fig. 3 is for furnaces above 24 tons' capacity, three-phase current, each phase maintained entirely separate from the others, with each end of each phase terminating in an electrode above the bath.

The most favorable shapes for tilting electric furnaces would appear to be:

Up to 6 tons: Rectangular in plan and in elevation with a curved bottom.

From 7 to 24 tons: Octagonal in plan.

Above 24 tons: Octagonal with lengthened back and front walls.

Stationary furnaces should always be rectangular.

The above shapes ensure the most convenient position for the electrodes in the furnace and help to keep the furnace walls at the average greatest distance from the electrodes, which should not be opposite to doors, in order to avoid the breaking of electrodes when material is thrown into the furnaces.

ARC PHENOMENA.

The arc phenomena in a steel-melting electric furnace are important and interesting. The arc proper jumps between the bath and whichever portion of the electrode is nearest. As this point is always changing, the arc travels irregularly round and under the lower extremity of the electrode. A flame of carbonaceous gas, in large furnaces as much as 2

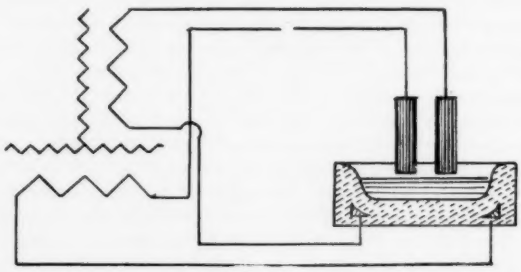


FIG. 1

feet long, travels over the bath from each electrode. This is quite the hottest flame in commercial use and in some designs of furnaces, causes excessively quick burning away of the roof and door arches. It will rapidly flux the banks of the furnace if allowed to impinge thereon. Some control can be obtained over the direction of the flame by alterations in the direction of rotation of the magnetic field of the supply currents. Experiments on the blowing of the arc flames in furnaces by strong external continuous magnetic fields were also made.

In some types of electric furnaces arcs are maintained between adjacent electrodes and not between electrodes and bath. The property of inter-repulsion of arc flames is utilized to fan the flames over the material to be melted, while much of the heat energy in the circuit, viz., that in the arcs proper,

*Abstract by the *Electrician* (London) of a paper read before the Institution of Electrical Engineers.

travels only between the electrodes. This leads to a high current consumption per ton of steel in such furnaces. It was once believed that the great heat (*circum.* 3,600° C.) of the arcs in an electric furnace would have a detrimental effect on the steel. More recent experience teaches us that, so long as a steel is thoroughly deoxidized before casting, only the temperature of casting is of moment.

TRANSFORMERS.

One might, with reason, say that the heart of the electrical equipment of an electric furnace installation is the transforming apparatus. The stresses which the transformers have to resist are exceedingly heavy. The plant has to with-

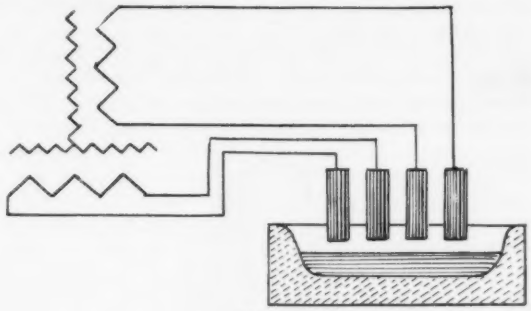


FIG. 2

stand occasional short-circuiting through the furnace and even the equivalent of almost a dead short-circuit. It has to allow frequent breaking of the circuits under heavy overload and, possibly, of occasional switching direct on to overload.

The requirements in the design of the transformers are:

1. That the current density of both the low-tension and extra-high-tension windings shall be low enough to prevent the inevitable overloads from unduly heating up and deteriorating the insulation.

2. The ventilating channels in the windings must be specially well considered so as to provide low resistance paths for the cooling oil without excessive magnetic leakage.

3. That windings shall be braced on all sides.

4. The low-tension windings shall be taped with such material as empire tape, in addition to press-spahn or similar stiff insulation.

5. All clamps, no matter how small they may be, should be anchored to the transformer frame work.

6. The whole of the apparatus must be as unyielding to magnetic stresses as mechanical skill can make it.

7. As much as possible of the total reactance required in the whole of the furnace installation should be incorporated in the transformers.

As a result of observations of the breakdown of some furnace transformers, the bracing of all sides of the windings of transformers was specified by the author in 1917. The design has now been standardized also for large power transformers.

It is usual to have several tappings brought out from the high-tension windings of furnace transformers, as the voltage required on a furnace during melting is higher than when finishing a heat. Such tappings should be brought away from the central portions of the winding, the complete high-tension winding being divided into two at the mid-point and the tappings bridged across the mid-point to cut out equal portions of each half of the windings when required. The insulation of the end turns of the high-tension windings can then be suitably reinforced to withstand any abnormal voltage stress on switching in the transformers. Useful results have been obtained by limiting the current density in transformer windings to 1,250 ampere per square inch, the induction in the iron to about 12,000 C.G.S. lines, and the temperature rise on continuous full load to 45° C., measured by the increase in resistance. An over-potential test at this double voltage is made on the high-tension side. Low-tension windings of large furnace transformers should be tested at a potential several times greater than normal.

AUTOMATIC ELECTRODE REGULATORS.

The desiderata in automatic regulation mechanism include sensitiveness without fragility, and simple setting to limits. If the furnace circuits contain two arcs in series, the energy in each such two arcs should be balanced, whatever current is flowing. This is accomplished in Stobie electric furnaces by operating one electrode motor by an automatic current controller and the other by an automatic potential controller. The current controller is adjusted to give the limits of current required and will keep its electrode at any position at which such desired current will flow. The potential controller is adjusted so that half the phase voltage, *i. e.*, the normal voltage between one electrode and the furnace charge, is maintained on the electrode it controls. The result is that the potential-regulating motor will keep its electrode at the same distance from the molten steel as the current-regulating motor keeps the other electrode, as at that distance the current will be normal and the voltage balanced. On some electric furnaces balancing of two arcs in series is automatically controlled in a different manner.

POWER FACTOR.

The power factor of alternating arcs varies from almost unity to lower than 0.7 in the case of arcs between cold hard metals. As is known, the apparent resistance of an arc varies with the current passing through it, being high for a low current. The voltage wave consequently is distorted and forms a sharp peak at the commencement and end of each half cycle, with a strongly marked depression between. The current wave approximately retains its sine shape, and a lagging power factor results without any phase displacement.

The circuit reactances are divided between the transformers and the leads. Due to the large sizes of conductors used, and to the large area enclosed by the circuits, reactance in furnace work has a tendency to be high. At the same time, very low reactance would be undesirable on large power systems in view of the frequent short-circuits through the furnace. The total impedance on short-circuiting through a cold charge will usually be high enough to reduce all shocks to reasonable limits. If, however, a short-circuit takes place through a molten steel bath, the impedance will be relatively low on account of the good conductivity of the bath, unless a reasonable amount of reactance is incorporated in the circuits. Such short-circuits are, fortunately, very rare in well-designed fur-

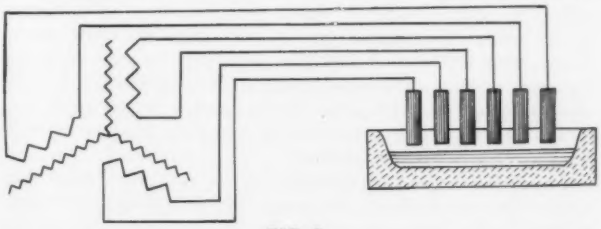


FIG. 3

naces. The total impedance at the moment of starting a large furnace with poor scrap sometimes reaches over 90 per cent. With average scrap it ranges between 40 and 60 per cent. When melting armor scrap or other clean heavy material it little exceeds the reactance

A 15-ton Stobie furnance gives the following power factors:

On melting	0.84
When charge is half melted	0.85
When charge is almost melted	0.87
When charge is melted	0.93

It can be safely stated that large furnaces such as the 10-ton, 15-ton, and 20-ton Stobie furnaces give an average power factor of fully 0.88 over all units consumed.

The author has heard it stated at various times that one or other particular design of furnace can be worked safely at

almost unity power factor. The author aims at installing plant in such a manner that on dead short-circuit the power factor is momentarily reduced to 0.4 or even 0.3.

ELECTRODE CONSIDERATIONS.

The presence of electrodes in electric arc furnaces is, for the user and designer, an unfortunate necessity. The desirable characteristics of an electrode are: low resistivity, relative incombustibility and cheapness. No material combines these qualities. The nearest approach is found in carbon, and one has the choice between amorphous and graphitic carbon, electrodes. The following table gives the comparative data of both types of electrodes:

	Specific resistance per cm. cube.	Lowest temperature of combustion.	Diameter to carry 10,000 amps.
Amorphous electrode....	0.00332 ohm.	513°C.	12 in.
Graphite electrode.....	0.00114 ohm.	624°C.	20 in.

A very important point, almost invariably overlooked by designers and users of electric furnaces, is "skin effect." The average current density in the main current-carrying area of an electrode being roughly twice the average current density of the whole area, due to skin effect.

The main consumption of the electrodes in ordinary electric steel furnaces does not take place at the arcing end of the electrodes, but results from the surface burning of the carbon all over those parts of the electrodes which are inside the melting chamber and up to a point about 15 inches above the roof. Fully 75 per cent of the heavy expenditure on electrodes is wasted through this defect. Various attempts to prevent this costly waste of electrodes have been previously made, such as (1) enveloping the carbons with asbestos paste held in position by wire netting; (2) coating the electrodes with non-burning paints; (3) encircling the electrodes with steel collars held together by hinges or springs; (4) surrounding the electrodes with water-cooled cyliders extending well inside the furnace. All such methods have met with failure.

It is thought by some people that there is always a reducing atmosphere inside electric furnaces. This is an utterly mistaken notion. The cause of the oxidizing atmosphere inside the older electric furnaces is the crude method of feeding the electrodes into the melting chamber, *i. e.*, by leaving in the roof a number of plain holes equal to the number of electrodes which have to be continuously fed into the furnace; the bricks forming such holes support annular water-jackets which fit, with a small clearance, new electrodes. The heated gases inside the furnace continuously pass up those clearances between the roof and the electrodes. As a result the clearance being increased by the flames burning away the electrodes to a tapered point, the heat value of the gases and flames which are constantly pouring out of the furnace through the electrode holes is wasted.

The clearance may be closed in this way: At about 2 feet above the roof in most furnaces the electrodes, even when raised for charging, are seldom at a temperature at which they can burn, therefore, that is the only point at which a permanently good seal can be made round the electrodes.

In practice, a light metal cylinder a few inches larger in diameter than the electrode and about 2 feet in length is fixed on the roof round each electrode. The top end of the jacket is covered with a sealing plate, the electrodes passing through a neatly fitting hole in the center of such cover.

Fig. 4 shows the present-day economizer, which can be applied in telescopic form suitable for furnaces having only a short electrode travel. Other advantages of this simple device are as follows:

1. No cold air is drawn into the furnace.
2. No flames burn away the electrodes above the roof.
3. A really reducing carbon-depositing (when desired) atmosphere is maintained within the melting chamber.
4. The oxygen-free atmosphere of the furnace prevents the burning of the electrodes inside the furnace except at the arcing ends, and, therefore, electrodes do not taper.
5. The electrodes can be of smaller diameter for a given current supply, thus diminishing electrode costs and permiting a reduction in the size of the electrode holes in the roof.
6. The life of the roof is increased because the thick carbonaceous atmosphere inside the furnace acts as an opaque curtain through which the intense heat of the arcs cannot be radiated upwards.
7. The flames inside the furnace, not being able to pass out at the electrode holes, travel all over and among the charge and heat this up readily and very economically.
8. The electrode gear over the furnace does not become intensely hot as in older furnaces. Any adjustments can, therefore, be made in comfort.
9. In consequence of the exclusion of free air from the furnace, and the absolute control which this permits over oxidation, scrap steels containing oxidizable elements, can be easily melted without losing the special elements from the bath.

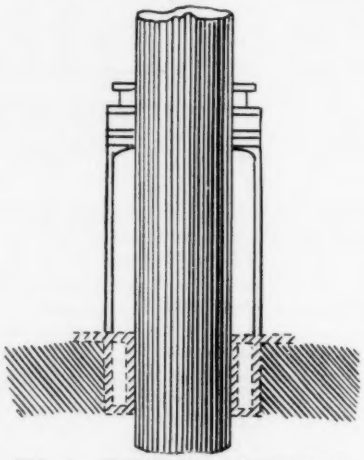


FIG. 4. ELECTRODE ECONOMIZER

10. The absence of heat from the electrode gear enables the current terminals of the electrode to be made of light copper contacts built up of standard copper bars, instead of intricate, heavy, water-cooled bronze castings.
11. By preventing the heavy heat losses which formerly took place, the cost of manufacturing electric steel has been reduced and the time required per heat diminished.
12. The sealing of the roof of furnaces results in the furnace being much cooler for the furnace men to operate.

CIRCULATION OF BATH.

It was decided to devise means whereby closer observation of the effects of electric circuits through molten metal could be made than was possible in a steel furnace working at temperatures up to 1,800° C. Mercury presented itself as a suitable substitute for a hot steel bath, being magnetically inert. Its resistivity at atmospheric temperature is approximately two-thirds and its specific gravity twice that of molten steel.

Separate experiments with single, two-phase and three-phase currents, and representing every known type of furnace with arcs playing on the bath, were made.

Two voltages were separately used for each system of connections; one low enough to enable the full current to be passed through the bath without arcs, and a higher one to pass the current through arcs above the bath as in normal steel melting.

The research conclusively proved that no circulatory or other stirring movement of the bath results from the electrode circuits in an electric arc furnace. The more or less complete diffusion of added elements which takes place in a bath of molten steel is a metallurgical phenomenon, and does not depend upon magnetic or convection currents.

The Hvid Engine*

Its Relation to the Fuel Problem

By E. B. Blakely

IT has been estimated that internal-combustion engines now furnish approximately two-thirds of all the prime motive power generated in the world. These internal-combustion engines may be roughly divided into three classes:

a Those burning gasoline

b Those burning kerosene, tops and other light distillates, after being started and warmed up on gasoline

c Oil engines of the Diesel, semi-Diesel, hot-bulb and surface-ignition types, which use for fuel crude oils, fuel oils and cheap grades of kerosene.

Of these three classes the first furnishes about 95 per cent of all prime motive power, and it has been estimated that there are in use now in this country, burning gasoline, nearly 4,000,000 automobiles, 250,000 trucks, 500,000 motor boats, 75,000 tractors and 750,000 farm engines. Is it any wonder, therefore, that the demand for gasoline has increased?

By ordinary distillation methods, Eastern crude oils yield from 20 to 30 per cent of gasoline, Mid-Continental crudes from 16 to 20 per cent, and Gulf, California and Mexican oils from 2 to 3 per cent. The rough average of these is 15 per cent. The visible supply of crude oil is naturally diminishing, and since the oil is becoming heavier all the time the percentage of gasoline yield is lessening.

The supply of gasoline may be increased slightly by making use of the cracking processes, which would necessitate an increased cost of production, and also by blending high-test casing-head gasoline with kerosene, a process bound to be short-lived because our gas wells are rapidly giving out. The supply of gasoline may also be conserved by increasing the thermal efficiency of the engines and by adapting them to burn kerosene and mixtures of gasoline and kerosene. The relief gained, however, would be but temporary at best. We are having trouble enough now in burning properly the present-day gasoline without trying to burn all sorts of mixtures which at the least would necessitate constant changing of carbureting adjustments and methods.

Much has been written and said during the past two or three years on the subject of using kerosene as fuel in conventional gasoline engines of both the slow-and high-speed types, and while undoubtedly much has been learned concerning the characteristics of kerosene under certain conditions, the burning of kerosene in gasoline engines, so far as the writer knows, has not been accomplished with complete success up to the present time. By complete success he means starting the engine on kerosene in atmospheric temperatures approximating 0 deg. fahr. and below (for these must be reckoned with) without preliminary heating of any sort and burning the kerosene so as to eliminate troublesome carbonization and complicated and unsightly accessory apparatus, and obtain high economy.

In attempting to burn kerosene in modified gasoline engines we are confronted by the following basic difficulties: Kerosene and gasoline are chemically widely different substances, having nothing in common but the base from which they are derived. Their initial boiling points are wide apart, that of commercial gasoline being about 100 deg. fahr., while that of kerosene is about 330 deg. fahr. Their boiling ranges are also totally different, that of gasoline being 240 deg. fahr., while that of kerosene is about 200 deg. fahr. Gasoline-air mixtures will ignite spontaneously at approximately 680 deg. fahr., while similar mixtures of kerosene and air self-ignite at approximately 575 deg. fahr. Mixtures of gasoline and air form a permanent fixed gas, but mixtures of kerosene and air do not, Under these conditions a jet carburetor designed for vaporizing gasoline cannot be expected to vaporize kerosene. The best it can do is to atomize it.

In order to vaporize, as well as to prevent precipitation or condensation of the atomized kerosene in the combustion chamber, it is necessary to heat the charge, and since the power output of the engine depends upon the amount of oxygen taken in and burned during each cycle, it is clear that the more the charge is heated the less oxygen we can get into the cylinder and the less power we can obtain. This forces us to a compromise between two conflicting conditions: the maintenance of the incoming charge at the lowest possible temperature which will vaporize the kerosene, and the prevention of precipitation in the combustion chamber. This compromise might be satisfactorily effected in the case of an engine running at a constant speed and load, but in the case of an engine running at varying speeds and loads it is a very different compromise to make, because as the power demands on the engine vary, so must the total amount of heat added to the charge vary.

In order to obtain maximum power from any internal-combustion engine, regardless of the kind of fuel used, we must have maximum mean effective pressure, and since mean effective pressure depends largely upon compression pressure, we must use the highest compression pressure possible. This brings us again to a conflicting pair of conditions, because in order to prevent so-called preignition with its attendant disagreeable and harmful pounding, when burning kerosene we are forced to use a relatively low compression pressure, which lowers the mean effective pressure and also the power output.

In this connection may also be mentioned the so-called preignition knock which occurs when using too high a compression pressure with kerosene. This knock is not caused by preignition as is generally supposed, but by small detonations after ignition has occurred and the piston has started downward. These detonations are due to the fact that kerosene is of a very complex chemical make-up and that after ignition has started the conditions are most favorable to cracking it. Under these conditions the kerosene breaks down into simpler combinations, some of which are highly detonating and others less so, and these compounds set one another off successively, according to their stability, but so rapidly as to produce a single knock.

FIG. 1. FULL-LOAD INDICATOR CARDS OF ENGINE RUNNING (A) ON KEROSENE AND (B) ON GASOLENE (200-LB. SPRING)

That this is so, is clearly shown by comparing the two full-load indicator cards shown in Fig. 1. They were both taken from the same engine but with different cylinder heads and operating with different governors. When *A* was taken the engine was running on kerosene (43 deg. B.) with no water injection, after having been warmed up on gasoline. A throttling governor was used. When *B* was taken the engine was operating on gasoline (62 deg. B.) and with a "hit-and-miss" governor. The compression ratio was 5 to 1.

Many engineers believe that if the problem of utilizing kerosene for fuel in these engines now burning gasoline could be solved, the whole fuel problem would be solved. It undoubtedly would help the situation immeasurably, but who can

*Paper presented at the Annual Meeting, December 1919, of *The American Society of Mechanical Engineers.*

doubt for a moment that the price of kerosene would not soar, once the demand for it began to grow, until finally there would be but little difference between the prices of gasoline and kerosene. The true economic solution of the fuel problem lies not in trying to adapt some particular fraction of the distillation of crude oil to the engine, but in adapting the engine to the available fuel, whether it be crude oil just as it comes out of the ground, or some by-product of its distillation.

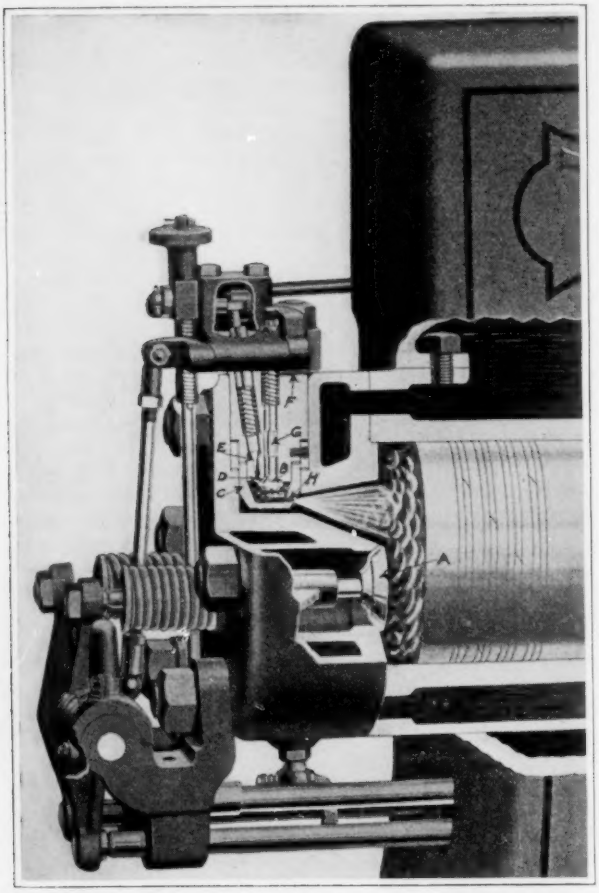


FIG. 2. CUTAWAY SECTION OF 8 H-P. HVID-TYPE FARM ENGINE

There have been numerous engines built in the last ten years capable of running consistently on the various crude and fuel oils, as for instance the Diesel and so-called semi-Diesel engines, hot-bulb and surface-ignition engines. These, however, have been used mainly in marine work and in relatively large units. It is out of the question to consider making Diesel engines of much less than 100 hp. per cylinder, because of the complicated fuel-injecting mechanism and the high cost of production. The other types have the disadvantage of requiring external preheating before they can be started, and the torches used for this purpose are a source of constant danger. Electric preheating has been tried, but with little success.

There is an engine, however, which has all the advantages of the above mentioned types and none of the disadvantages. This is the Hvid engine. It can be started cold on any liquid fuel which will flow through a pipe. It has no complicated air-compressor system for injecting the fuel, no hot bulbs or torches, and runs with a fuel economy on a par with the Diesel engine. The Hvid engine can be and is being produced in units as small as 1½ hp., and so economically as to be able to compete with gasoline engines of the same size.

ADVANTAGES OF THE HVID ENGINE

A comparison of the Hvid engine of the farm type with a conventional gasoline engine of the same type discloses many factors which show the superiority of the former for this class of work. The Hvid engine has neither electrical devices nor carburetor or mixer. It starts readily on any liquid fuel, even in the coldest weather. On the other hand, the conventional gasoline farm-type engine has electric ignition, which is frequently a source of trouble. It has a carburetor or mixer to be adjusted according to atmospheric conditions and quality of fuel, and finally the gasoline engine is very hard to start in cold weather.

Briefly enumerated, the chief advantages of the Hvid engine are:

a Mechanical simplicity
b Low fuel consumption at all loads
c Ability to start and run on any oil which will flow
d Low water-jacket losses
e No lubricating difficulties
f Constant compression
g Remarkable torque characteristics
h Absence of all electrical devices, hot bulbs and torches for ignition purposes
i Absence of all carbureting mechanism
j No carbon troubles.

The Hvid engine is of conventional four-cycle type, embodying the usual inlet and exhaust valves, timed to open and close as in any four-cycle engine. The compression pressure is carried to between 425 and 475 lb. per sq. in., which heats the compressed air to between 900 and 1000 deg. fahr. In the cylinder head there is a fuel-admission valve terminating in a small steel cup by means of which a preliminary explosion is made to force the fuel into the combustion space. Referring to Fig. 2, the Hvid cycle is as follows:

Suction Stroke. During the suction stroke pure air is admitted to the cylinder through intake valve *A*. Fuel valve *B* is opened in synchronism with intake valve *A* and some fuel flows into cup *C* out of hole *D* which is uncovered by the opening of valve *B* (the fuel enters cup *C* partly by gravity and partly by inhalation). The amount of fuel admitted is controlled by the metering pin *E*, which in turn is controlled by the governor. At the same time that the fuel is being inhaled into the cup, a small amount of fresh air is also drawn through an auxiliary air hole *F*, down past a fluted guide *G* into the cup *C*. At the end of the suction stroke, fuel valve *B* and air-intake valve *A* close, valve *B* sealing the fuel-admission hole *D*.

Compression Stroke. During this stroke all valves are closed and the air admitted to the cylinder on the suction stroke is compressed to about 420 lb. per sq. in., which raises its temperature to between 900 and 1000 deg. fahr. In other words, there is now a mass of highly heated air under high pressure in the combustion chamber and this rushes into cup *C* through small holes *H* near its bottom until the pressure in the cup is practically equal to the pressure in the combustion chamber. The conditions in the cup are now most favorable to "cracking" the oil, and as the oil cracks the lighter and more volatile components are detonated by the high temperature and the resultant high pressure within the cup forces the rest of the oil out into the air in the cylinder. The amount of fuel consumed in the cup per cycle is infinitesimal because there is only a very small amount of air present in the cup to support combustion.

Power Stroke. As the fuel in an atomized and vaporous state comes into contact with the heated air in the combustion space, very rapid combustion takes place and the pressure arising from it drives the piston.

Exhaust Stroke. As in any four-cycle engine, the exhaust valve opens and the products of combustion are forced out by the piston.

INDICATOR CARDS

Fig. 3 shows a series of indicator cards taken from the 8-hp. Hvid engine of Fig. 2, as well as one from a 20-hp. engine of the same type. Descriptions of these cards follow.

Card *A* is a no-load, stop-spring card which shows a slight vacuum during practically the entire suction stroke and figures approximately 375 ft. per sec. through the inlet orifice; at the same time it shows good volumetric efficiency. This vacuum is maintained intentionally for the reason that there is left in the injector cup, after the expansion and exhaust strokes, a slight residual pressure which interferes with the regular delivery of fuel by gravity. Dropping the suction pressure slightly below atmospheric removes this cup pressure, gives a slight pull on the incoming fuel and makes for close governing.

Card *B* is one taken from the inside of the injector cup with the main air-intake orifice not choked and shows a residual pressure in the cup even during the suction stroke of the engine. One of the greatest difficulties encountered in early Hvid engines of the farm type was consistent governing, and it was not until automatic inlet valves were discarded and the inlet-air velocity was maintained constant that good governing was possible. Card *C* is a full-load card and card *D* is a 25 per cent overload card.

Card *E* is a full-load card from an 8½-in. by 10-in. 20-hp. Hvid engine in which the ignition point is much more clearly defined than in the cards taken from the 8-hp. engine. There is no doubt that ignition takes places at relatively the same point on the smaller engines, but the speed of the smaller engines is so much higher that the ordinary indicator fails to show it.

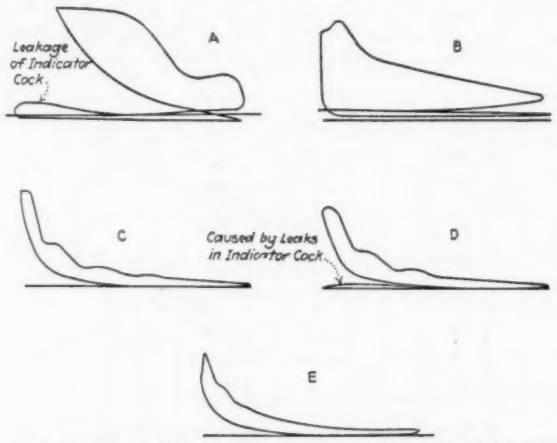


FIG. 3. INDICATOR CARDS TAKEN FROM HVID ENGINES

It is interesting to note the waves in the expansion line of these cards. These are typical of all cards taken from Hvid engines and are caused by the introduction of fuel into the combustion chamber in waves. At the moment when the preliminary combustion takes place in the cup, we have in the cup a pressure of approximately 800 lb., while in the combustion chamber there is a compression pressure of only 425 lb. Some fuel is consequently sprayed out of the cup into the combustion chamber by the attempt at pressure equalization. When the fuel comes in contact with the highly heated air in the combustion chamber, the pressure rises in the combustion chamber and falls in the cup until equalized; then no more fuel can get out of the cup until the piston moves forward and the pressure in the cylinder drops below that in the cup, when some more fuel is ejected from the cup. This is repeated until there is no more fuel left in the cup.

FUEL CONSUMPTION

The fuel consumption of small Hvid-type engines is very good, being in general on a par with Diesel engines of large size. If Diesel engines could be economically constructed in units as small as Hvid engines can, it is doubtful whether they would compare at all favorably in thermal efficiency with the small Hvid units on account of the mechanical inefficiency of the air compressors necessary to inject the fuel. In the comparative fuel-consumption curves shown in Fig. 4 the fuel economy of the Hvid engines as compared with two other types of the same size stands out very plainly, particularly at the lower fractional loads. The "hit-and-miss" gasoline test in Fig 4 was made by Professor Dickinson of the University of Illinois, the throttling-governor kerosene test by Mr. MacGregor of the Hercules Gas Engine Company, under the supervision of Government experts, and the Hvid-engine test by the writer under the supervision of Professor Roesch of Armour Institute. The engine used in each case was a 5¾-in. by 9-in., running 450 r.p.m. and rated at 8 hp.

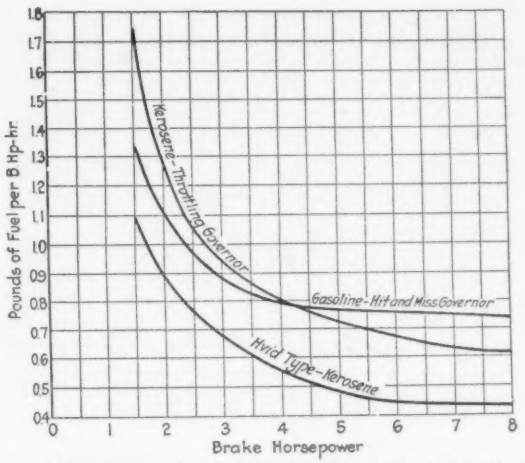


FIG. 4. COMPARATIVE FUEL CONSUMPTION CURVES OF 5¾ ×9 IN FARM-TYPE ENGINES OPERATING ON DIFFERENT PRINCIPLES

The fuel-consumption curve of the small 3-in. by 4½-in. Hvid engine shown in Fig 5 is particularly interesting because this engine, running at 1100 r.p.m. normally, is the first relatively high-speed engine of this type built. When it was first designed the writer was very skeptical as to the results to be expected from it, because, owing to the high speed, it was natural to suppose that trouble would be encountered with the time element necessary for the introduction of fuel into and ejection out of the cup; but it was found that this little engine could be run at speeds as high as 1500 r.p.m. without any apparent interference with the perfect operation of the Hvid principle. In fact, the faster it was run the better the results. Based on its performance several engineeers connected with the production of Hvid engines raised the normal r.p.m. of their engines with very beneficial results.

Professor Roesch also supervised other tests made to determine the entropy diagram and the heat balance, while Mr. H. C. Knudsen made tests for torque. It is worth while to record here the results of these tests.

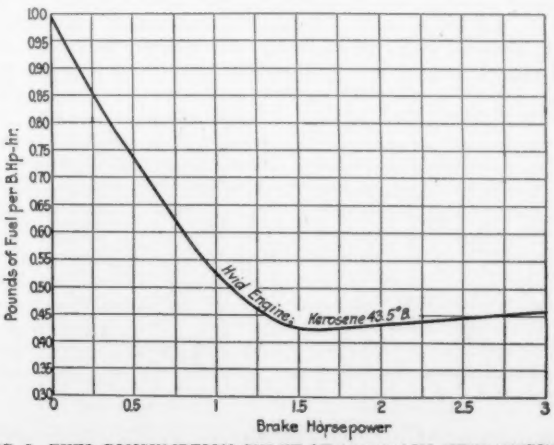


FIG. 5. FUEL-CONSUMPTION CURVE OF A 3×4½ IN. HVID ENGINE

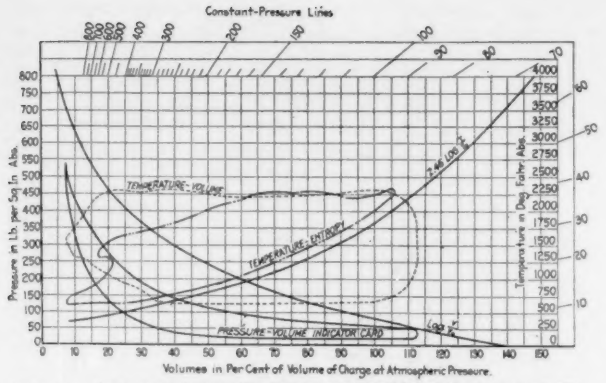

Constant-Pressure Lines
TEMPERATURE-VOLUME
TEMPERATURE-ENTROPY
PRESSURE-VOLUME INDICATOR CARD
Pressure in Lb. per Sq. In. Abs.
Temperature in Deg. Fahr. Abs.
Volumes in Per Cent of Volume of Charge at Atmospheric Pressure.

FIG. 6. VOLUME-TEMPERATURE DIAGRAM FOR A 5¾ × 9 IN. SINGLE-CYLINDER HVID KEROSENE ENGINE

Entropy Diagram. The entropy diagram, shown in Fig. 6, was plotted from a pressure-volume indicator card taken from a 5¾-in. by 9-in. single-cylinder Hvid-type engine running at 450 r.p.m. and using kerosene as fuel. This diagram is submitted because it shows the general temperature characteristics, which are quite different from those in an explosive gasoline engine. It is interesting to note the low maximum temperatures, 2300 deg. fahr. abs., as compared with the maximum temperatures for gasoline engines, which frequently run as high as 3000 to 3500 deg. fahr. abs., and also the sustained temperature in the Hvid engine throughout the working or expansion stroke. At first glance it might be argued that this sustained temperature would be harmful because of undue heat losses to the water jackets, but since the water-jacket losses are low and the thermal efficiency of the engine is remarkably good, the writer believes that combustion in the Hvid engines takes place in the form of zone burning and that the cylinder walls are more or less insulated from the high temperatures of combustion by a layer of air which is not burnt until near the end of the stroke.

Heat Balance. This test gives the mechanical efficiency and the thermal efficiency for both brake and indicated horsepower. It was made upon a 5¾-in. by 9-in. single-cylinder Hvid engine which was flexibly connected to a Sprague electric cradle dynamometer by means of two "Spicer" universal joints. Engine speeds and fuel weights were obtained by means of electrically operated appliances. Arrangements were also made for determining the jacket-water loss and the sensible heat of the exhaust gases (calorimeter method). The developed and friction horsepower were determined by means of the dynamometer. Indicator cards were also taken, but because of the probable errors due to the high pressure involved and the comparatively high speed of the engine, these cards were used merely to study the valve settings and general events of the cycle, and not for indicated power measurements. The engine was operated under various loads and speeds with various adjustments of fuel supply, compression and cup design. The final setting was made with a compression of 390 lb. per sq. in.

Test runs, curves for which are shown in Fig. 7, were conducted at various loads from a maximum to about one-eighth of maximum load, and readings were taken to determine the following:

1 Friction horsepower (electric-dynamometer method)
2 Brake horsepower (torque and speed)
3 Jacket-water loss
4 Sensible heating in the exhaust (calorimeter method)
5 Loss due to radiation and incomplete combustion (by difference)
6 Fuel consumption (lb. per hour).

Items 1 and 2 are determined directly from dynamometer readings; items 3 and 4 are calculated from observed temperatures and weights; item 5 is determined by difference; and item 6 is obtained from direct measurements. The heat value of the fuel expressed in B.t.u. per lb. of kerosene is calculated from the following accepted formula:

$$\text{B.t.u.} = 18{,}440 + 40 \times (\text{deg. Baumé}—10)$$

and is 19,740 B.t.u. for the quality of fuel used in the test runs.

Torque. In Fig. 8 are shown some of the torque characteristics of the Hvid engine. When a gasoline engine of conventional design is overloaded so that the speed drops beyond a certain point its torque drops rapidly, because a certain velocity of air must be maintained through the carburetor to pick up and vaporize the fuel and carry it into the cylinder; but in a Hvid engine, since the introduction of fuel into the cup and into the cylinder is not dependent upon the velocity of the air taken

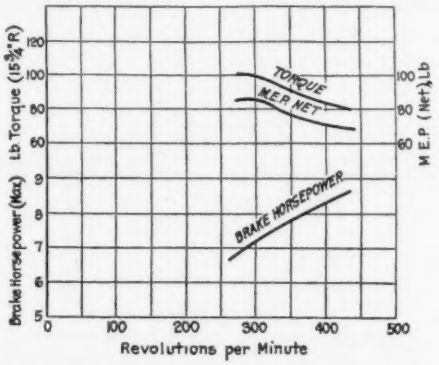


FIG. 8. BRAKE-HORSEPOWER AND TORQUE CURVES FOR A 5¾ X 9 IN. SINGLE-CYLINDER HVID ENGINE

in, as the speed drops, due to overload, more fuel is admitted than at normal speed, because the time element for the introduction of fuel is lengthened and the engine consequently shows remarkable "hanging-on" characteristics.

Under these conditions it is very wasteful of fuel without a doubt, but there are certain conditions where this "bull dog" characteristic is desirable even at the expense of fuel economy. Mr. Knudsen states that these values were actually obtained on the test block but that he is of the opinion that under actual operating conditions the torque should not be allowed to climb quite so high for the lower speeds, the reason being that the engine smokes badly and takes too much fuel at speeds below 450 r.p.m. It would seem to be better practice to vary the opening of the fuel valve with the speed of the engine, so that a curve could be plotted, giving maximum torque at different speeds with a uniformly clean exhaust.

In conclusion, the writer would say that while the Hvid engine has by no means reached its ultimate state of development, it nevertheless possesses a number of wonderful characteristics which ought to attract many internal-combustion engineers by the possibilities they hold out of helping to solve some of our fuel problems.

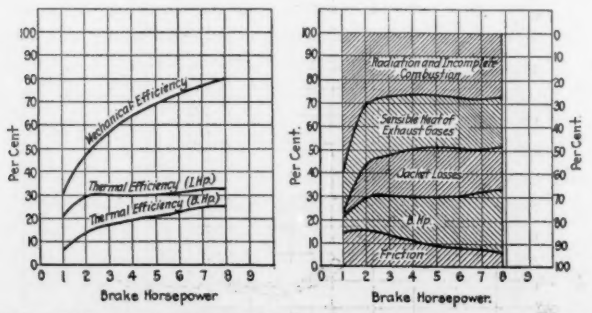


FIG. 7. HEAT BALANCE AND EFFICIENCY CURVES FOR 5¾ × 9 IN. SINGLE-CYLINDER HVID ENGINE

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

THE National Research Council is a group of scientific, technical and business men organized under the Congressional charter of the National Academy of Sciences, with the coöperation of our National scientific and technical societies, educational institutions, the industries, and independent specialists. The Council was established in 1916, to coördinate the research facilities of the country for work upon war problems, and in 1918, by executive order of the President of the United States, it was reorganized as a permanent body.

The National Research Council is a cooperative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

While enjoying the hearty coöperation and support of the various Government departments, the Council is not a Government bureau, nor is it financed by the Government. Its duty is to promote research, both scientific and industrial, and to encourage the training workers capable of engaging in research and applying its results. It is to this organization and its work that we wish to introduce the readers of the SCIENTIFIC AMERICAN MONTHLY Magazine.

It has been the history of the race that many of our most valuable lessons have been learned as a result of the stimulation derived from such an upheval as a war, and, frequently, the greater the conflict the greater has been the ultimate good which has come from it. In a discussion on "The National Importance of Scientific and Industrial Research," by Dr. George E. Hale in Bulletin No. 1 of the National Research Council, this point is emphasized and the following quotation from de Tocqueville is cited:

"When a violent revolution occurs amongst a highly civilized people, it cannot fail to give a sudden impulse to their feelings and ideas. This is more particularly true of democratic revolutions, which stir up at once all classes of the people, and at the same time beget high ambitions in the breast of every citizen. The French made surprising advances in the exact sciences at the very time when they were completing the destruction of the remains of their former feudal society; yet this sudden fecundity is not to be attributed to democracy, but to the unexampled revolution which attended its growth."

Perhaps it may have been due to the gigantic scale upon which the late war was conducted, or perhaps not, but whatever the reason the extraordinary degree to which coöperation between all classes and interests was secured, was one of the outstanding features of the war activities, and one of the lessons which we must not forget. When it is remembered that the industrial problems of peace are in a large measure the same as those of war, although with a somewhat different emphasis, the importance of continued coöperation is difficult to overestimate. This is particulary true in the case of pure and applied science upon which our continued progress annd property depend. That this view is universally held is amply illustrated by the world-wide effort to organize science. With this movement some of our foreign friends were identified before the formation of our own National Research Council, but in these cases there is an essential difference in that the foreign organizations have been developed under the auspices and control of their respective governments and have been made a part of the government organization.

In Great Britain as early as July, 1915, a committee was appointed by the Privy Council for the purpose of directing the application of any money provided by Parliament for the organization and development of scientific and industrial research. This committee appointed an advisory council and in December, 1916, the work of the committee first appointed was established under a separate Department of State, which has since been designated "The Department of Scientific and Industrial Research." This department is responsible to a minister of the Cabinet, and has been intrusted with the expenditure of some five million dollars to stimulate and support, as well as coördinate, scientific investigation in Great Britain for the benefit of the Empire. The work done under the direction of the advisory council and the department during the war was indispensable to the success of the military establishments of the Empire, and the effort of the department is now directed toward the formation of coöperative research associations among those concerned with the same class of materials, the encouragement of research workers, and the organization of national research under which classification are to be found problems, the solution of which belongs more to the Government than to any private group. Among such investigations may be noted the question of mine-rescue apparatus, researches with reference to building materials including home-grown timbers, and extensive researches relative to fuel and food, and to industrial fatigue.

As for the research associations established by industries, eight have been incorporated, a like number have been approved but not licensed as yet, and a number of others are engaged in completing their arrangements and drafting articles of association.

In addition to these efforts on the part of Great Britain herself, the Dominions, especially Canada and Australia, have made substantial progress in like organizations while plans are well under way for similar activity in India, New Zealand, and South Africa.

Japan has also established a National Laboratory for Scientific and Industrial Research, with a fund of two and one-half millions of dollars for use during the next ten years.

Italy has prepared to continue the work undertaken in 1916 by the Office of Inventions and Research which was then created under the Department of the Ministry of Arms and Munitions. The Italian National Research Council is now in progress of formation and will conduct its work under seven divisions of science.

Science for years has assisted in the organization of many lines of effort, but in so doing has neglected to organize itself. The National Research Council represents a unique effort at thorough organization of American science, and the success which resulted from such organization and coöperation during the war gives every reason to believe that the National Research Council will be even more successful under peace conditions, than it could be during the exciting times of war. The duty of the National Research Council is the promotion of research, both scientific and industrial, and in the terms of the executive order issued May 11, 1918, by the President of the United States, its functions are as follows:

"In general, to stimulate research in the mathematical,

physical, and biological sciences, and in the application of these sciences to engineering, agriculture, medicine, and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare.

"To survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects.

"To promote coöperation in research, at home and abroad, in order to secure concentration of effort, minimize duplication, and stimulate progress; but in all coöperative undertakings to give encouragement to individual initiative as fundamentally important to the advancement of science.

"To serve as a means of bringing American and foreign investigators into active coöperation with the scientific and technical services of the War and Navy Departments and with those of the civil branches of the Government.

"To direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the war, and to aid in the solution of these problems by organizing specific researches.

"To gather and collate scientific and technical information at home and abroad, in coöperation with governmental and other agencies, and to render such information available to duly accredited persons."

In order to carry out this important program, the membership of the National Research Council has been chosen with a view of rendering the Council an effective federation of the principal research agencies in the United States concerned with the fields of science and technology. The work has been organized along division lines, the divisions themselves being of two classes: first, those dealing with the more general relations of the Council, and, second, those concerned with related branches of science and technology.

There are six divisions in the first group.

The Government Division.—Chairman, Dr. Charles D. Walcott, secretary of the Smithsonian Institution, in which are represented the various scientific bureaus and groups of the Government. This division will have very important work to perform in obtaining an even greater degree of coöperation in Government and scientific matters than has heretofore been possible and through its conferences and discussions many new methods of attack and entirely new subjects for research may result.

Division of Foreign Relations.—Chairman, Dr. George E. Hale, director of the Mt. Wilson Solar Observatory and foreign secretary of the National Academy of Sciences. This division includes representatives of the Department of State, of the National Academy of Sciences, The American Association for the Advancement of Science, and the American Philosophical Society. The division is further strengthened by having as a member the Hon. Elihu Root, former Secretary of State. There are a great many problems in fundamental science which are international in their scope and of such character that they do not properly come under the divisions of science and technology. These questions will have the attention of the Divisions of Foreign Relations which, through its connections abroad, will be in a position to maintain close contact between investigators in similar fields in those countries with American workers, to their mutual advantage.

Division of States Relations.—Chairman, Dr. J. C. Merriam, of the University of California. This division has for its purpose at present the study of the relationships of the various agencies within a State which are concerned either with the development or the application of scientific knowledge. In the work of certain committees organized by State Councils of Defense to meet war conditions there is much to indicate the value of concerted action in pushing forward scientific investigations upon matters affecting public welfare. It is hoped that in many cases State committees can be organized for the purpose of bringing about more complete coöperation between the various State scientific bureaus, the scientific departments of its colleges and universities, the scientific aspects of its industries and matters of conservation, as well as of public health. It seems obvious that such committees should regard the needs of a State and its resources in men, institutions, and materials with which to meet these needs, from a wide angle of view and with a long reach into the future. The division is now placing its plans before those who are interested both in the progress of knowledge and the fundamentals of science, and the application of this knowledge to all phases of public good, in the hope that it may have the benefit of consideration from many points of view and thereby be able to associate its activities so as to accomplish as much as possible. The division reaches a great diversity of interests through its membership.

The Division of Educational Relations.—Chairman, Dr. Vernon Kellogg, of Stanford University. This division bases its work upon the principle that a fundamental factor in the advancement of learning and civilization, insofar as this is dependent upon education, is the ability to conduct research progressively. Inasmuch as the large majority of research workers are to be found in the universities and colleges upon which we must also depend for the development of new workers and that it is on these institutions that we must depend for the development of new workers, it is incumbent upon us to assist in creating the atmosphere and the opportunity favorable to the stimulation and activity of scholars and those are to become scholars. The membership includes officially appointed representatives of all the universities associations and the United States Bureau of Education, together with a number of members at large, among whom may be mentioned Abraham Flexner, secretary of the General Education Board, H. S. Pritchett, president of the Carnegie Foundation for the Advancement of Teaching, and Herbert Hoover.

It is felt that we have reached a stage in the progress of research where we may well pause to consider what the conditions are which at present hinder research in American colleges and universities, or which, if more fully developed, would permit of increased productivity in research. One of the first activities of the Division of Educational Relations will be to seek the coöperation of institutions of higher education in a study of these conditions. This study has already been actively begun.

Division of Industrial Relations.—This division has for its chairman, Dr. John Johnston, of Yale University, and its membership includes representatives of Government bureaus, of the Naval Consulting Board, industrial research laboratories, chemists, engineers and business men. The division endeavors to stimulate a better appreciation of the necessity of applying all the science at our command to our industrial problems and to support and engage in researches in fundamental science, in order that there may be more knowledge without which the solution of many production and process problems will be impossible. This division has carefully considered the present situation with respect to industrial research and has launched its activities with a proposal to organize an association for alloys research, which association will be made up of both consumers and producers of alloys, who can jointly support research on the fundamentals of pure and alloyed metals. In several special branches of industry progress awaits determination of chemical and physical constants, with respect to the composition of metallic mixtures. The field is so broad that no one concern would be justified in doing all of the work as thoroughly and as fundamentally as is needed. At the same time, the advantage to the respective members of the association will in the end depend upon their ability to apply the data thus secured, so that the proposed investigations present an unusually attractive opportunity for coöperative effort into which no spirit of commercial competition need enter. The division has prepared a tentative outline for the formation of such an association and, following a discussion with those most interested, will soon be inviting

manufacturers to become members on a basis that seems certain to make unusual returns for the expenditure. The division has also initiated work with respect to research in the great cotton industry, and in coöperation with the World Cotton Conference, held in New Orleans in October, 1919, plans to assist the various branches of the cotton industry to unite on some research policy and to engage actively and consistently in the prosecution of research. A start has already been made by several of the associations in the cotton trade, but there seems to be an opportunity to correlate these movements and for this purpose the Chairman of the National Research Council and the presidents of the National Association of Cotton Manufacturers, the American Cotton Manufacturers' Association, and the American Society for Testing Materials have been asked to join in the appointment of a small committee which will survey the work in America, outline problems which should be undertaken immediately, suggest methods of attack, and prepare a budget for the consideration of the various associations which must join in financing and organizing the specific work. This question has an international phase, for cotton is a commodity of universal importance and some features of the problems must be considered in other cotton-growing and consuming countries. It is contemplated that eventually research associations in the cotton industry will undertake various special problems simultaneously for the good of all and for the direct benefit of the race.

Special attention is drawn to the American Association of the Baking Industry and its recent accomplishment in establishing an American Institute of Baking, for which the National Research Council is about to appoint an advisory committee. The division of Industrial Relations has had some part in assisting the association in its work and it is a pleasure to be able to say that the baking industry is about to begin, through its Institute, a program of applied science in which the people at large are directly concerned. In addition to research into the fundamentals of the baking industry, there will be specialists available for work upon problems of production and a center will be established which will greatly assist in directing the education of those now engaged or about to engage in the baking industry. Problems of nutrition—the possibility of producing an equally nutritious and palatable loaf at a lower price, the best method of handling various flours and the possibility of using the many food products which science is constantly improving without lowering the actual value of the baker's product, indicate but one or two of the important problems which face the Institute. Dr. H. E. Barnard for a long time associated with the Indiana State Board of Health and Federal Land Administrator of Indiana during the war, becomes the director of the institute.

There are many other special fields in which an effort will be made to have research undertaken on a more extensive plan, either in the laboratories of the industries, in existing laboratories both of the university and commercial type or in new ones to be established in special instances.

Research Information Service.—Dr. R. M. Yerkes, formerly of Harvard University, is the chairman of this division. The service maintains a large permanent staff and is really a clearing-house and information bureau for scientific and industrial research. The service seeks to promote research by supplying individuals or institutions with such information, or to advise concerning research projects, the location of special equipment, an indication of methods of attack, the problems now being solved or proposed for solution, or with published results, to the end that coöperation may be encouraged, duplication lessened, support increased, and the exchange of reports concerning progress in related investigations promoted. By increasing the efficient distribution of research effort, it is certain that greater wisdom may be exercised in the choice of problems and it is one of the objects of the service to assist in reaching this desired end. This is, of course, a large program and for the present the service seeks to develop, as its principal mechanisms of exchange, a carefully cross-referenced catalog of current scientific investigations, a similar list of research laboratories, a list of investigators with suitable cross-references, a catalog of sources of scientific and industrial information, and such bibliographies, digests, etc., as are incident to this work. Obviously, to accomplish this purpose, the Research Information Service must have the coöperation of all investigators and such cooperation is invited. The extent to which directors of laboratories and investigators generally can give their assistance will determine the success of this important undertaking, and there is every reason to believe that those who are willing to assist will receive far more than they contribute. This is not an attempt to centralize and control scientific work, but an effort to be of greatest possible service.

At the moment, several important publications are in preparation or are on the press, the first being a bulletin on "The National Importance of Scientific and Industrial Research" by a number of authors. "Research Laboratories in Industrial Establishments of the United States" is the title of another bulletin soon to go to press, in which the industrial research laboratories, their location, special fields of work, size of organization, unusual equipment, etc., will be tabulated and cross-indexed for the benefit of the industries and those concerned in their application of science.

The divisions of the second group are those of science and technology, seven in number. The organization of work of this character has been difficult since in any effort of this kind careful precautions must be taken to do nothing which might discourage individual effort or initiative. That many of the notable advances in science have been made by individuals, many of whom work more or less in a state of isolation, is well recognized, but it is equally clear that in many instances such a genius, if provided with proper assistance, will accomplish far more than would otherwise be possible. It is believed that coöperation can accomplish this, and the situation is well expressed by the following paragraph from the correspondence files of the Council:

"Without the personnel, without the laboratory and the great factory facilities, I become but a single, isolated unit and worth but a few per cent of my value as part of that developed organization."

In practically all cases, any division or committee activity has necessarily been preceded by a careful survey of the special field in which it is working. The object first of all is to become acquainted with the present status of investigations in order to determine where the gaps and missing links are so that new effort may be directed toward filling them. Such conferences and discussions have also served to bring together those interested in various phases of a common problem, and this always results in much benefit to those concerned. The Council in all its work seeks to avoid duplication of any work well organized and in good hands. In many cases, its divisions have been able to encourage those now engaged upon the solution of some problem, have suggested new lines of attack, have been able to locate special apparatus and sometimes to increase the number of workers in a particular field or to secure the interest of new workers in checking over the work, duplicating some of the experiments for confirmation and preparing the data for publication. In some instances duplication is unnecessary, while in others it is highly desirable to conduct similar experiments in different laboratories to reduce errors due to personal equation, and likewise to conduct the experiments under the different conditions which naturally exist in various laboratories.

Division of Physical Sciences.—Chairman, Dr. C. E. Mendenhall, of the University of Wisconsin. The American section of the International Geophysical Union has been a committee of this division. The American branch of the International Astronomical Union is undergoing reorganization following

successful activities as a committee of this division, while steps are about to be taken to organize an American branch of the International Mathematical Union, which will have important work to perform. A number of research committees to study conditions in various fields of the physical sciences are in process of formation, and at present 15 committees are devoting attention to such important subjects as "X-ray Spectra," "High Vacua," "Theory and Practice of Wireless," "Acoustics," "High and Low Temperatures," "Aeronautics," "Magnetism," and "Spectroscopy." The division is carrying on coöperative work with the Division of Chemistry and Chemical Technology on the tables of critical data, and also in the administration of the research fellowships, which will be mentioned below.

Division of Engineering.—Chairman, Dr. C. A. Adams, of Harvard University. This important division has been organized with the coöperation of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, the American Society of Civil Engineers, the American Society for Testing Materials, the Society of Automotive Engineers, the American Society of Illuminating Engineers, the Western Society of Engineers. Its personnel is composed of officially appointed representatives of these societies, together with 12 members at large. The Engineering Foundation is represented by five members, one of whom is the chairman of the Engineering Foundation. When one considers the broad field of engineering, especially as represented by the societies indicated above, it is apparent that this must be one of the most active divisions of the Council. So far, its work has proceeded under the direction of some 20 special committees, and the problems upon which study is being directed are all of immediate importance to industry at large. Its committee on pyrometers has made a report in the form of a symposium at the Chicago meeting of the American Institute of Mining and Metallurgical Engineers, and more than 90 important papers were presented. The committee on fatigue phenomena has in progress very interesting work from which may come practical methods for determining in advance when the stresses to which metal is subjected in use have carried it nearly to the breaking point, so that replacements and repairs can be made in advance of annoying or even disastrous breaks. Some of the other important subjects are: "Pulverization." "Standardization of Bearing Metals," "Uses of Alloyed Steels," "Welding Research," "Improvements of Metals at a Blue Heat,' "The Heat Treatment of Carbon Steel," "The Elimination of Inclusions from Steel" and "Electric Insulation."

Division of Chemistry and Chemical Technology.—Chairman, Professor W. D. Bancroft, of Cornell University. In the organization of this important division the American Chemical Society, the American Electro-Chemical Society, the American Institute of Chemical Engineers, and the American Ceramic Society have been active. The special duties of this division seem to fall into three special phases: *first*, securing coöperative research on fundamental things; *second*, the suggestion and assignment of special research problems; and, *third*, the bringing together of men in different fields. It is thought that often the research student may as well be assigned some problem which will supply missing data in some broad plan rather than to undertake some other line of work which may be just as important in itself but of less consequence at the moment because it is not correlated with work that has been done. Hence, lists of suggested problems are being compiled with the purpose of suggesting them to those who are concerned with the direction of graduate students and others interested in research. In this division there is a committee on explosive investigations, of which Dr. Charles E. Munroe is chairman, and the work they are undertaking has the direct support of the Departments of War and Navy and the Bureau of Mines of the Department of the Interior. The activities of this special committee will be discussed in greater detail in subsequent reports. Other committees, all including men in the forefront of their fields, are: a committee on synthetic drugs; one on the chemistry of colloids; another on the thermal properties of explosive materials; a committee on caramics research; another on sewage disposal; and another on chemical journals. In addition, a committee on the teaching of organic chemistry is being organized, with the hope that it will be able to make suggestions that will improve the teaching of organic chemistry in our universities. It seems important that more stress should be laid on qualitative organic chemistry, a field which has not thus far had the attention it deserves.

Naturally, the Division of Chemistry is called upon to coöperate with many other divisions. Thus, it is interested with the geologists in developing a theory of sedimentary rocks. The applications of colloid chemistry are of direct interest to the biologists, and there are many points in common with the physicists. A problem of unusual importance is the production of different kinds of pure, rare sugars by means of which various bacteria may be identified and differentiated, which is in the field of medicine. The Division of Chemistry is directly concerned in the National Research Fellowships, to be referred to later.

Division of Geology and Geography.—Chairman, Dr. E. B. Mathews, of Johns Hopkins University. While geological and geographical matters have been pretty well organized by various State and Federal agencies, it has become evident that the Division of Geology and Geography can do a great deal of constructive work in surveying the entire field and attempting to have certain gaps in the information supplied by means of new researches. The division is also in a position to act as a clearing-house for information and to bring together men widely separated geographically, who would each profit by knowing the activities of the other, the direction his work is taking, and the present status of his investigation. In some cases, work on a problem has ceased when some individual has been compelled to drop it, and frequently it is well worth while for another investigator to take up the thread and endeavor to solve the problem. The aim of the division is to work with existing organizations and to support their efforts rather than to establish a new agency of research which might have conflicting interests.

Division of Medical Sciences.—Chairman, Dr. H. A. Christian, of Harvard University. To indicate the many lines in which the Division of Medicine is interested would involve a discussion too lengthy for this present announcement. Plans are being made for investigation of medical problems in industry at the suggestion of the Engineering Foundation; also certain activities in neurology and psychiatry are under consideration. Work on intestinal parasites, anaerobic bacteria, and studies of pacific therapy and allied problems, in coöperation with chemists, are being outlined. There are a number of coöperative investigations which are to be undertaken with the physicists and questions of publication in the biological and anatomical fields, upon which work is being done. There seems to be an opportunity for constructive work in international indexing, abstracting, and the critical review of scientific literature, as well as a possibility of establishing a central bureau of information regarding technical methods which are applicable to the medical sciences.

While many of the divisions are interested directly in the International Research Council and its activities, none is more concerned than the Division of Medical Sciences, and great expectations are held for the ultimate success which will attend international effort in the suppression of communicable diseases and epidemics in their earliest stages in the areas from which they are believed to spread.

Division of Biology and Agriculture.—Chairman, Dr. C. E. McClung, of the University of Pennsylvania. This important division has a number of projects in the hands of several committees, some of which work in close coöperation with other divisions of science and technology. Some of these commit-

tees have been the outgrowth of similar ones in the Council during the war organization and work begun then can be profitably carried on under the present organization. Typical committees are those on food and nutrition and on forestry. In them are representative leaders in the sciences and their projects are of vital concern to the public. The Committee on Food and Nutrition is divided into a Subcommittee on Human Nutrition and a Subcommittee on Animal Nutrition, with special reference to animals of agricultural importance. The object here is to promote scientific research upon food and nutrition problems and to bring about closer relations between the two fields of work represented by the subcommittees. A study of the economics of nutrition and its national and international phases as distinguished from personal nutrition, is to be undertaken. Efforts will be made to promote coördination of both American and foreign research and to conduct authoritative propaganda work in the interest of better nutrition. The funds which have been intrusted to the National Research Council are for the support of its general organization, so that any special undertaking must be financed independently. Therefore, an appeal will shortly be made for additional funds with which to carry out the work of the committee above mentioned and it is encouraging to be able to say that one of the large food companies has already entered into an arrangement to contribute to the support of the researches proposed.

The Committee on Forestry appeals to a great number of industries which will be directly benefited by the work it has in hand. The forest problems of the nation are so large that some such coöperative body is essential to their early solution, and without the data which cannot be obtained otherwise than by such research studies, it is obviously impossible to formulate a rational forest policy for all parts of our country. One of the problems upon which this committee will work is systematic measurements on thousands of representative areas well-distributed over the forest regions of the United States to determine how rapidly our second-growth timber is producing the amount and kinds of merchantable timber which our industries will require in the not distant future. The solution of this problem is more difficult than appears on the surface, for it involves the succession of vegetation on cut-over land and is closely allied with another problem, which is the standardization of lumbering practice and forest treatment, to insure the self-perpetuation of forests.

It is well known that a certain type of forest does not necessarily follow itself but is often succeeded by an entirely different type of vegetation, sometimes of a shrub character. We therefore must study the effects on the second-growth of the different methods of cutting the old stands, and of different ways of handling the land after the cutting has been made. The proper use of fire must be determined, for in some instances the data indicate that the use of fire is beneficial in preparing the new seed-bed. We need to know more about the number and kind of seed trees which should remain per acre, and the effect of grazing upon the new stand. If a lumberman is to hold his cut-over lands until the new forest becomes of commercial value, it is essential that some method be devised whereby the land can be made to earn at least enough on the investment to pay the taxes and overhead expenses, and it seems possible that grazing, which involves the selection of the best forage grasses for the purpose, may prove to be the solution.

We also need to know more concerning the correlation between the biological factors and the physical, mechanical, chemical, and structural qualities of timber. All of these questions and many others involve coöperation on the part of federal and state agencies as well as a large number of individual workers. Funds will be required to carry out the work which will begin with a careful tabulation and study of present information and work in progress, in order that those agencies now in the field may be encouraged to supply the missing parts and new agencies have their efforts directed into the untilled fields from which additional data will be secured. This type of work directly concerns not only the lumber interests but those for whom wood is a raw material. In this list may be included the makers of wheels, handles, boxes, veneers, and the many specialties into which particular kinds of wood enter.

Division of Anthropology and Psychology.—Chairman, Dr. W. V. Bingham, of the Carnegie Institute of Technology. This division is just completing its organization, but something of what may be expected can be forecast from the activities of its predecessor in the war organization.

The tests of mental alertness for enlisted men, providing for those characteristics which are important in the aviation service, were prepared by this division, and the contributions of psychologists to the study of qualifications for flying and the psychological effects of high altitudes were of the first importance. Aid was rendered to the Division of Psychology of the Medical Department of the Army in administering mental tests to officers and enlisted men. The rating of soldiers according to mental alertness or degree of intelligence aided materially in the proper utilization of various grades of intelligence, and more than 1,700,000 individuals were examined. It was demonstrated that psychological methods could be devised and adapted to assist in selecting and training observers and scouts, and it was largely due to the efforts of the psychologists that a morale branch of the general staff was established and facilitated by the War Department. These military activities also extended to the selection of suitable look-outs for merchantmen, the selection of men for special assignment in gunfire squads, and to serve as listeners. It is a source of gratification that the methods devised by the division are proving of great assistance to those worying independently in the classification of workers. This sort of work can be profitably extended to study of school children and others, with the result that special instruction can be undertaken in time and much lost effort saved.

It will be seen from the above that all the sciences are more completely represented in one central organization to a greater degree than has ever before been attempted in this country, and this alone is very important, for remarkable achievements have always resulted from the cross fertilization of the sciences.

While the successful research worker must be a specialist in a narrow field, he often finds the application of methods and apparatus of another science to be to his undoubted advantage, and any man is broadened by coming in contact with those having principal interests quite different from his own.

National Research Fellowships.—It is not enough merely to encourage research; we must also help to provide men to engage in fundamental research and it is, therefore, very fortunate that the Rockefeller Foundation has provided a fund of $500,000 to be expended during the next six years under the direction of the National Research Council for National Research Fellowships in Chemistry and Physics. These fellowships have for their purpose the confirmation of exceptional young men in pure research in these sciences and the increase in the amount of available knowledge secured by making it possible for the exceptional research worker to remain in his field devoting himself to fundamentals at the time when he can accomplish most, namely, immediately following the receipt of his doctor's degree. These fellowships are unique in that the fellow may choose not only the subject of his research but the place at which he will study, and the Council undertakes to encourage research in the university chosen by arranging for suitable facilities so that the work may be properly carried out.

The National Research Council, in order to perform its duties, must be kept free from undue political and industrial influences. It therefore derives its support from a wide, democratic backing, and it is confidently believed that its results will be such as continually to win even wider support.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

BLOWERS FOR AERO ENGINES.

DESCRIPTION of blowers built in Germany for use in supercharging aircraft engines at high altitudes.

The blowers are of the centrifugal type. Three or four stages are directly driven off the engine shaft, suitable provision being made to prevent torsional oscillation. The delivery is regulated by throttling the air intake of the blower. The carburetor has to be compensated for variations of air pressure in the usual manner. The speed of rotation is very high—10,000 to 11,000 r.p.m., and special steels are used for the rotors. The weight of a blower complete with fittings suitable for an engine 260 hp. and capable of reproducing ground-level conditions up to 15,000 ft. is 125 lb. The power consumed is about 25 hp.—*W. G. Noack, in Flugsport*, Sept. 19, 1919, abstracted through *The Technical Review*, Oct. 28, 1919.

GASOLINE ENGINES FOR STREET-RAILWAY CARS.

DISCUSSION of the respective merits of the two types of propulsion for street-railway service. The writer claims that while the gasoline motor is excellent for certain classes of service such as automobile and truck work, it is not suitable for street-railway cars.

The electric motor is almost ideally suited for street-railway service. Its speed-torque characteristics meet the requirements as the electric motor has the enormous starting torque of the over-load capacity and flexible speed characteristics necessary to give the rapid acceleration and different speeds for street-railway service. In point of reliability it also stands very high and its cost of maintenance, depreciation and power are all relatively low.

The gasoline motor can make street cars run, but its speed-torque characteristics are not well adapted for the work. Thus, it absorbs from 25 to 30 per cent of its normal amount of power when running idle. It has no starting torque and very little torque at low speeds. Gear ratios help to balance this weakness, but at best the gasoline motor would give a very poor acceleration for a street car unless it were very much overmotored.

The reliability of the gasoline motor is also claimed to be less than that of the electric motor.

As regards costs, it is claimed that they would be higher for gasoline cars because the cost of maintaining the transmission on motor trucks and motor buses is very high. It is also claimed that the life of a gasoline motor is shorter than that of an electric motor.

It may be well to call attention, in this connection, to the fact that whenever the author speaks of motors for street-railway service he compares the electric motor with the airplane-type gasoline motor, which is, of course, the very last thing that could be thought of for applying in street-railway service. —*N. W. Storer*, in *Aera*, October, 1919, pp. 375-378.

DETERIORATION OF NICKEL SPARK-PLUG TERMINALS IN SERVICE.

THE most commonly used material for terminals in spark plugs is commercial nickel wire containing about 97 per cent nickel, the remainder being manganese, cobalt, iron, copper and minor impurities. The peculiar type of deterioration that occurs in these nickel terminals during the service life of the spark plug was recently brought to the attention of the Bureau of Standards, the present paper giving the main results of the investigation.

It has been found that the deterioration of the central terminal was quite negligible compared to that of the side terminal or terminals. These latter wires had developed, in service, transverse cracks that in many cases were as sharp and definite as a knife cut. After a separation occurred the bridge widened by loss of material from ends of the fractured wires until a gap of as much as one centimeter often resulted. The fragments of the deteriorated wire terminals removed from the spark plugs were found on the whole to be rather ductile and stand several sharp right-angle bends before breaking. The extreme end portion immediately adjacent to the break, however, was brittle and broke readily when an attempt was made to bend it.

The examination of the central terminal showed that a change of the same character as occurred in side terminals had taken place in this one also, but to a far less extent.

The tests would indicate that variations in chemical composition such as occur in commercial nickel wire are not a determining factor in the deterioration of the wire in service. Terminals of nickel of relatively high purity were found to be attacked in the same manner as others of lower nickel content. Oxidation of the nickel does not appear as being of great importance in this connection, and the action of hot reducing gases, though somewhat greater than that of oxidizing, does not appear to be very great either.

It would appear that the main cause of embrittlement of the wire lies in the intense local heating by means of the electric spark, together with the sudden cooling, and that once the formation of transverse intercrystalline cracks has started the application of a relatively low stress to the hot wire is sufficient to fracture the wire.—*Henry S. Rawdon* and *A. I. Krynitzky*, in *Bulletin of the American Institute of Mining and Metallurgical Engineers*, August, 1919, pp. 1323-1350.

COPPER DIFFUSION THROUGH CAST IRON.

WHEN a malleable-iron bar packed in copper oxide packing and annealed at 1,000 deg. cent. was taken from the furnace it was found that the copper oxide was reduced to metallic copper, which latter was melted and penetrated into the iron. An average sample of the bar showed that the carbon

FIG. 1. CROSS SECTION OF GRAY-IRON BAR ANNEALED IN COPPER OXIDE PACKING

had been reduced from 2.70 to 0.60 per cent and that there was 21.4 per cent copper.

The test showed for this bar a strength of 68,200 lb. per sq. in. and an elongation of 1 per cent in 2 in. The electrical conductivity of the metal was not materially increased by the presence of the copper.

In other tests the test pieces were packed in black copper oxide and heated to about 900 deg. cent. The results were different and a far smaller penetration of copper was observed.

With gray iron quite different results from those for malleable iron were obtained. This is illustrated in Fig. 1, which shows a cross-section of one of the bars. Three distinct areas can be seen. The area *A* contains all of the copper. There is a thin layer of copper on the outside and next to this the copper is very finely divided and is in the form of droplike areas surrounded by a matrix of iron. This matrix has a peculiar structure and is more like steel than it is like gray iron. The line between *A* and *B*, Fig. 1, is shown in Fig. 2. The dark area is the portion containing the copper. The light portion in the same figure represents the structure of the section marked *B* in Fig. 1. The same structure is seen in

FIG. 2. DIVIDING LINE BETWEEN *A* AND *B*, FIG. 1

FIG. 3. STRUCTURE OF *B* AND *C*, FIG. 1

the upper section of Fig. 3, which is part of the dividing line between areas *B* and *C*. This structure is almost like the structure of malleable iron in its appearance under the microscope, but scattered through it can occasionally be seen flakes of graphite.

The center of the bar *C*, Fig. 1, has the structure of unchanged gray iron. This is shown in the lower section of Fig. 3.—*H. E. Diller, in The Foundry*, November 1, 1919, pp. 779-780.

TIN FUSIBLE BOILER PLUGS.

DATA of an examination, at the Bureau of Standards, of tin fusible boiler plugs for the Steamboat Inspection Service and of the tests made subsequently.

The experimental results show that there are six primary causes for the rejection of fusible plugs which may be roughly divided into two classes. Under the first class, rejections are included due to mechanical defects of casing material. The second class includes rejections due to lack of purity of the tin filling. The impurities in the latter case may be those either present in the original tin or those introduced during the manufacture of the plug.

The following conclusions have been reached as to the precautions to be taken in the manufacture of fusible plugs:

1. The pig tin should be at least 99.7 per cent pure, containing not more than 0.1 per cent lead, or 0.1 per cent zinc, which are the requirements of the Steamboat Inspection Service.

2. The casing should be of bronze, an alloy the major constituents of which are copper and tin. Small amounts of zinc and lead increase the ease of casting and machining and are not objectionable if not present in greater amounts than in the following compositions:

	I	II
Copper	88	87
Tin	10	7
Zinc	2	5
Lead	..	1

3. The pot or crucible for melting the tin should not be used for melting other metals, thus doing away with the liability of contaminating the good tin when these are not thoroughly cleansed.

4. Casings should be tinned on the inside with the same grade of tin used for filling, but the tin left over from this process should not be added to the filling to be used. Zinc-chloride flux may be used although hydrochloric acid if preferred, though no flux need be used during the filling process.

5. The casing should be preheated to not above 250 to 275 deg. cent. (482 to 527 deg. fahr.) and tin should be poured at a temperature not above 275 to 300 deg. cent. (527 to 572 deg. fahr.).—*J. Gurevich* and *J. S. Hromatko*, in *Bulletin of the American Institute of Mining and Metallurgical Engineers*, August, 1919, pp. 1351-1360.

ORIFICE MEASUREMENT OF WATER-PIPE DISCHARGE.

THE thin-plate orifice may be used with confidence for measuring the discharge of water through pipes. Like nearly all methods, it is subject to some limitations, although it helps to fill a growing need which has been partly filled by the pitometer and by the injection of chemicals. The pipe orifice is in effect a portable venturi meter, the disadvantage of the pipe orifice being the relatively large lost head caused by the obstruction of the orifice plate; however since the pipe orifice method is probabzly best adapted to temporary use the lost head caused by the orifice would be relatively small. Cases in which the pipe orifice should be of particular value have already been suggested in the introduction.

Although all the deductions and conclusions given in this summary apply to the measurement of water, attention should be called to the fact that the pipe orifice is adapted to measuring the discharge of air, gas, and steam through pipes.

The following points are important as a guide to the proper use of the pipe orifice method of measuring the discharge of water through a pipe:

1. The two sections of the pipe between which change in pressure head may be most reliably determined are the section at which normal flow is discontinued and the stream begins to converge as it approaches the orifice, and the section of greatest contraction of the jet after it leaves the orifice. Regardless of the size of pipe, for all sizes of orifice which it is feasible to use, the distance from the plane of the orifice to the section of beginning of convergence may be taken as eight-tenths the pipe diameter, and the distance of the section of greatest contraction as four-tenths the pipe diameter.

2. The drop in pressure head between these two sections is greater than that to be found for any other two sections near the orifice.

3. Having given the measured difference between the pressure head at the section of beginning of convergence and the pressure head at the section of greatest contraction the discharge may be determined through the use of one of two equations given in the original paper. (In one of these equations there is used a coefficient of discharge which is a variable quantity.) It decreases as the size of pipe increases; it decreases slightly as the drop in pressure head increases; it has a minimum value for orifices having a diameter of one-third that of the pipe and increases as the diameter of the orifice becomes greater or becomes less than one-third the diameter of the pipe.

4. The lost head caused by any given orifice in the pipe in terms of the velocity in the pipe may be determined by an equation given in the original paper, and is always less than the drop in pressure head between the section of beginning of convergence and the section of greatest contraction, but approaches it in value as the ratio of the diameter of the pipe to the diameter of the orifice (D/d) increases.

5. Due to the fluctuations of the liquid in the gage tubes the systematic error of reading the gage increases as the ratio of the diameter of the pipe to that of the orifice decreases, but when that ratio (D/d) is 2 or greater the error may under normal conditions of flow be reduced to a negligible quantity by a proper manipulation of apparatus. As (D/d) becomes less than 2 the accidental error of reading the gage increases very rapidly, and also small errors in the measurement of the diameter of the pipe or the diameter of the orifice are likely to be the constant sources of an error of increasing magnitude in the computed discharge. The indications are that, for favorable conditions of flow and with care in installing the apparatus and in observing, discharge may be determined generally within 2 per cent when the diameter of the orifice is not in excess of two-thirds that of the pipe, but this size of orifice seems to be about the maximum that can be used except for approximate determinations of discharge. When the magnitude of the lost head is not the controlling factor in the choice of size of orifice, best results are likely to be obtained if the diameter of the orifice is not greater than one-half that of the pipe.

6. For orifices having a diameter greater than one-half that of the pipe the use of two opposite pressure openings at each section is important because of the probability of the orifice being somewhat eccentric with the pipe, unless greater care is taken in placing the orifice than will usually be found practicable. Systematic errors of observing may be greatly reduced by proper throttling.

7. The coefficient of discharge for bevel-edged orifices is a much more variable quantity and is materially greater than the coefficiency of discharge for thin square-edged orifices. The use of the bevel-edged orifice seems not to be practicable, except for approximate measurements when the orifice diamter is greater than two-thirds of the pipe diameter.—*Raymond E. Davis and Harvey H. Jordan*, in *The University of Illinois Bulletin*, Dec. 2, 1919.

TURBINE-GEAR DRIVE FOR TORPEDO-BOAT DESTROYERS.

THE design of propelling machinery for destroyers is an unusually difficult problem in view of the fact that a 1,200-ton destroyer requires propelling machinery of a capacity equal to that put into a 30,000-ton battleship and that this machinery must be operated by a force of 30 to 40 men in the small boat as against 200 in the large boat.

The relatively greater power required by the destroyer is due to its higher speed. The power required increasing approximately as the fourth power of the speed and the two-thirds power of the displacement. As the propeller speed can be increased with the ship speed, the speed of the propelling machinery can also be increased, in addition to which the type of machinery must be of the simplest form possible consistent with reliability and economy.

Increased rotative speed means decreased size and weight of driving machinery. The use of reduction gears allows the main turbines to have higher speeds, which, in its turn, leads to decreased steam consumption with the resultant decrease in weight of fuel necessary for a given cruising radius. Furthermore, with the high-speed geared turbines a relatively large number of rows of blades or stages can be used at slower speeds, at which the boat chiefly operates, which tends to give good efficiency at these speeds.

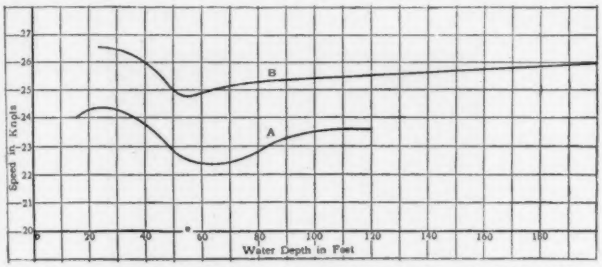


FIG. 4. SPEED CURVES OF DESTROYERS IN VARIOUS DEPTHS OF WATER AND CONSTANT INDICATED HORSE-POWER

The article gives brief information on the fuel economy of boats of the "Clemson" type compared with similar data of the U. S. battleship "Tennessee." It is of interest to note in this connection that in unofficial builders' trials on the "Clemson" at about 30 knots the machinery developed a shaft horsepower on slightly less than one pound of oil per hour, and that the boats reached a full speed ahead of 35 knots.

Interesting data are presented in reference to the influence of the depth of water in which a boat is moving on its speed. In general, the deeper the water up to at least one boat length, the faster the boat will go with the given propulsive power, but with long narrow boats of the torpedo or destroyer type there may be a shallow depth at which the boat speed will actually be higher than at any greater or lesser depth. This is shown in Fig. 4 made from trial data and has been confirmed in trials of the destroyers of the "Clemson" type.—*W. B. Flanders*, in *The Electric Journal*, November, 1919, pp. 474-476.

PRESENT LIMITS OF SPEED AND POWER OF SINGLE-SHAFT STEAM TURBINES AND TURBO-GENERATORS

THE steam turbine is a comparative new comer in the field of prime movers and it was only about ten years ago that units of 5,000 to 6,000 kw. were considered in the light of highly hazardous experiments. Today units as large as 60,000 kw. are considered to be perfectly practicable and both operating engineers and manufacturers of central station equipment are interested to know whether there are any limits, mechanical or economic to the size of turbines.

The general feeling seems to be that the chief limitations are economic, in that extremely large units are still very costly per unit of power developed and involve greater risks in case of disablement. At a recent meeting of the American Institute of Electrical Engineers representatives of the largest manufacturers of turbo-electric equipment in this country presented three papers of sufficient general interest to make the following abstract:

The first paper by Eskil Berg starts by showing that the limit of a single unit turbo generator does not lie in the generator, but is confined to the steam turbine and that the limiting feature of the latter is the last wheel. The paper is based mainly on the work done by the General Electric Company.

Questions of design of the large turbines and of the conditions limiting the size are discussed.

Efficient action of the blades in large-sized turbines operat-

ing with the high vacuum can be accomplished only by using the bucket speed that bears a proper relation to the steam velocity, which means that to get the largest capacity not only long buckets must be used but they must be moved at a very high speed. On the other hand, to obtain good bucket action the buckets should not be more than about one-quarter as long as the pitch diameter of the wheel.

The use of a high steam speed in the last stage naturally implies that a relatively large proportion of the total steam energy must be utilized there and such concentration of work into a single stage has its disadvantages even if the best relations of velocities is maintained.

Since such a stage is doing a large amount of work, it is naturally less efficient than a stage of similar character doing less work.

In this way the last wheel of the turbine becomes one of the limiting features of the over-all dimensions. Energy and efficiency curves (Fig. 5) of the last stage are given which show that at the most efficient point, this stage absorbs 11.5 per cent of the total adiabetic available energy and that the wheel efficiency is 66.25 per cent. But this is for an output of 21,000 kw. and in the same turbine when the load increases to 36,000 kw. the energy in the last stage is 20.9 per cent of the total energy and the wheel efficiency goes down to 54.2 per cent.

The conclusion which the author comes to is that for a given speed there is one particular size of turbine which can be designed to be most economical as to steam consumption, weight, space and price per kilowatt. Even if a size smaller than this is required, it would, in many instances, pay for the central station to install a larger unit, even though it would have to run at reduced load for some time before the station load increased sufficiently to utilize its full capacity.

F. D. Newbury discusses the conditions determining the size of a turbine and conditions limiting it.

In the opinion of the writer, maximum output at any speed when reduced to the simplest terms is attained when slot space is provided for the maximum possible ampere turns (in either stator or totor) and core cross-section is provided for the maximum possible flux.

These conditions require the most effective rotor diameter and the maximum rotor and stator core lengths.

The most effective rotor diameter for a given speed is not necessarily the largest diameter and to obtain maximum output at a given speed the rotor proportions must be chosen properly to balance mechanical stresses, rotor ampere turns and flux.

The electrical factores in generator design are discussed by the writer who believes, among other things, that a fundamental difficulty in setting down definite limiting outputs is the difficulty in arbitrarily setting limiting stresses.

On the other hand, limit of length of the rotor and stator cores is determined mainly by such considerations as cooling air requirements, bearing proportions, by limits to weight imposed by transportation facilities and the ability to secure forgings of necessary diameter and weight.

To give an idea of the character of these limitations, it may be stated that, for example, transportation facilities may impose a limit to size in the case of 6- and 8-pole 60-cycle generators. From the special nature of their design and the special skill and equipment required for winding and assembling, rotors should be completed at the builder's factory and shipped as a unit. The weight of the complete rotor of a 4-pole 1,800 r.p.m. generator of 40,000-kva. capacity will be roughly 90,000 lb. This can be transported without difficulty, but the largest possible 1,200-r.p.m. rotor would weigh more than 200,000 lb. and would require rolling stock and trackage in some cases not now available.

Another general limitation to output of larger diameter rotors is that imposed by the forging facilities of the country. At the present time it is not possible to obtain forgings of suitable physical characteristics weighing more than 50 or 60 tons nor much larger than 50 in. This limits the rotor made from a single forging to an output of roughly 50,000 kva. at 1,500 r.p.m. By adopting the rotor construction involving 2 or 3-in. plates and up-set flanged shaft ends, the limiting diameter may be increased sufficiently for the largest 1,500 and 1,200-r.p.m. outputs shown in Fig. 6.

This figure shows in curve form limiting generator capacities at various speeds. At 1,500 r.p.m. and higher the capacity is determined by the rotor and is inversely proportional to the r.p.m. squared. At lower speeds the capacity is limited by the stator and falls somewhat below the corresponding rotor limiting capacity, as indicated by the dotted expansion of the rotor curve. The curve is an indication of the present boundaries based on existing commercial materials and current stresses are bearing proportions. In fact, the capacities shown by it are somewhat in advance of accomplished results.

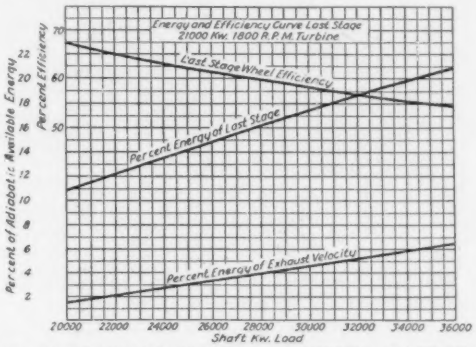


FIG. 5. ENERGY AND EFFICIENCY CURVES (LAST STAGE) OF A LARGE TURBINE

The writer claims that mechanical forces due to short circuit and damage caused by armature winding failures are no greater in the very large generators indicated by the above figure, than the present-day 20,000-and 30,000-kva. unit.

No opinion is expressed as to the wisdom of installing very large single-shaft units. If operating engineers desire units of 50,000 to 100,000 kva. there is no question but that such generators can be conservatively designed and constructed.

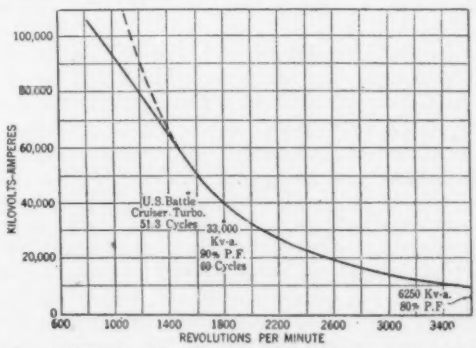


FIG. 6. LIMITING GENERATOR CAPACITIES AT VARIOUS SPEEDS

The paper by J. F. Johnson is restricted to a discussion of some of the factors which influence limits as applying particularly to turbines of the reactionary type. Here again the author expresses the opinion that with the employment of high vacuum the limit of power is determined largely by the area obtainable through the last stage, for the final expansion and passage of the steam prior to its entering the condenser.

The significance of this is shown by the fact that whereas a pound of steam when entering the first stage has a volume of less than 2½ cubic feet when passing through the last stage it has a volume of approximately 395 cubic feet if expanded to 28.5 in. vacuum, and 585 cubic feet is expanded to 29 in., the ratio in the latter case being 1 to 234.

Because of this, in any discussion of limits of power, it is necessary to assume conditions of pressure and superheat of the steam entering the turbine, the vacuum to which the steam is to be expanded in the blading and the efficiency of change of steam flow per unit of power.

The limiting factors are divided into three classes by the author. (1) Theoretical, including limiting steam velocities and effect on efficiency of velocity remaining in steam after leaving the last stage, and the area through the blades as affected by blade angle. (2) Physical, including methods of construction, materials, stresses, factor and safety against rupture, reliability factor, and limitations of transportation facilities; (3) Economical, including limits beyond which it may be physically possible but economically inadvisable to go, such as effect of size of structure or of character of materials employed on costs and time required to make inspection and repairs. The paper is largely based on the practice of The Westinghouse Company.

As regards theoretical limits with materials of infinite strength and rigidity it would have been possible to build units of infinite capacity, but for a given diameter and blade height the capacity is limited by chosen maximum values of steam speed through the blades, in order to keep the energy available in the steam discharged to the condenser within permissible limits.

Throughout the entire turbine, with the exception of the last few stages, steam speeds only about 25 per cent in excess of the corresponding blade speeds are employed in order to secure maximum efficiency. In the latter stages, however, the volumes become so great that steam speeds are increased sometimes approximately 100 per cent in excess of the blade speed, in order to effect a compromise between maximum theoretical efficiency and physical dimensions.

The question of blade angle is discussed next.

As regards the physical limits, the chief ones limiting turbine capacity are the physical characteristics of the material employed and the chosen limits to which these materials may be safely stressed.

Of course, the design of the rotor materially affects the stressed involved, but if the rotor design can be so modified as to keep the stresses within necessary limits, then the stresses at the base of the limits or in blade fastenings determine the maximum capacity obtainable with its given speed.

There exist two interesting relations between the stress at the base of blades, steam passage area through the blades, and rotative speed. For any given rotative speed and blade angle, the steam capacity or steam area through the blades is directly proportional to the stress at the base of the blades, regardless of the diameter and blade height selected. This stress can only be modified by unevenly varying the cross sectional area of the blades, such for example, as thickening the blade near the base. Also for any given stress the area through the blades will vary inversely as the square of the speed, *i. e.*, if at a speed of 1,800 r.p.m. a given stress and area are obtained, then at 900 r.p.m. the area will be increased four times if the stress is kept constant.

In other words, as the writer shows in the original article, the area and stress are each equal to a constant x the product of mean diameter and blade height and when the stress is constant this product varies inversely as the square of the revolutions per minute. The ratio of blade height to rotor diameter is therefore not a factor in determininng physical limit of capacity, but only in determining efficiency cost and, to some extent, reliability of the turbine.

Increased capacity without decrease of rotative speed or increase in stresses may be obtained by employing multiple low-pressure stages and a curve is given showing the limits of capacity of steam turbine with double-flow low-pressure stages.

In considering the economic limits of turbines of large capacity, consideration is given to the fact that as yet such units are not required in sufficient quantity to warrant equipping and operating shops for their exclusive manufacture, and that they must be produced largely by the same processes and equipment as are used for smaller sizes which are built in greater quantities.

As the sizes become larger, a greater proportion of special equipment and processes becomes necessary, resulting in increased rates of cost unless accompanied by very material increase in production of quantity.

Another factor tending to limit capacity of single units is the generating capacity loss resulting from suspension of service for inspection or repairs.—*Proceedings of the American Institute of Electrical Engineers*, Nov., 1919, pp. 1243-1253.

ITALIAN WATER TURBINES.

In the course of a tour through Italy and France, the author has seen under construction a rather unusual type of water turbine. It is to be used to produce power for the Italian electric state railways. The machine consists of two Pelton wheels of different diameters, employing varying heads of water, the water in question being drawn from two different sources of supply. Of the two wheels which are upon the same shaft, one is operated by a head of 2,000 feet and the

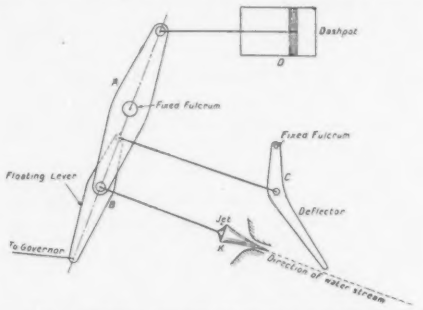


FIG. 7. RIVA SPEED-CONTROLLING ARRANGEMENT FOR PELTON WHEEL TURBINES

other of 670 feet. As a large variation of load occurs throughout the 24 hours, the plant is fitted with an automatic device by means of which a smaller wheel which is only used when the load rises to a certain point may be put to work. The diameters of the two wheels taken at the centers of the buckets are 6.4 ft. and 3.67 ft., respectively, and the speed 500 r.p.m. The larger diameter wheel develops 3,500 hp. with one jet and the smaller wheel 2,500 hp. with two jets.

An interesting feature of the Riva turbine of the Pelton type is the method of governing speed, or rather the control of the water jet. This is effected in two ways—first by deflection and next by throttling (Fig. 7). In it A is the lever working on a fixed fulcrum. To one end of this lever is attached a dashpot D; on the other end is fulcrumed the floating lever B. One end of this floating lever operates the deflection C and the other is connected with the governor. The fulcrum itself is connected with jet K.

Suppose the load to be suddenly removed from the turbine and raising commence. The governor immediately reacts on the floating lever B and the deflector comes into action on the water steam. Since resistance is offered in this operation to the turning of the lever B about its fulcrum, the fulcrum itself becomes a moving point about the fulcrum of the lever A and the jet K begins to close. The arrangement is really an application of the floating lever principle as used in various differential gears to this particular purpose.—*Norman Davey*, in *The Engineer*, Nov. 7, 1919, pp. 456-457.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

LIGHT WAVE TELEPHONY.

AN interesting series of experiments on the transmission of speech by light was described by A. O. Rankine in a recent communication to the Physical Society of London. The experiments showed that the method is practicable for considerable distances, while the fact that the apparatus is portable indicates that it may be of practical utility in certain cases. The theory of the process is given as follows, in the article:

The notable property of selenium of varying its electrical conductivity when exposed to illumination of various intensities has long been well known. It has led to various attempts being made during the last thirty or forty years to transmit

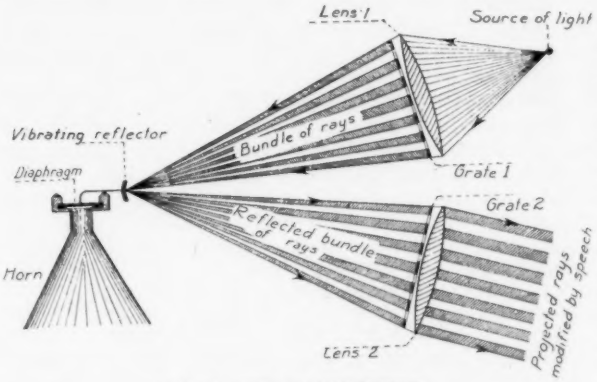


FIG. 1. THE TRANSMITTER

speech over considerable distances by means of a beam of light which fluctuates in intensity in a suitable manner. Given such a beam of light the mode of reproduction is simple. A circuit is made consisting of a selenium cell exposed to the beam, a telephone receiver, and an electric battery. If the intensity of the beam does not vary, the electric current through the telephone receiver remains constant. But, if there have been impressed on the beam fluctuations of intensity corresponding in amplitude and frequency to the vibrations of speech or other sounds, the selenium, if it is capable of adjusting its conductivity with sufficient rapidity, will control the current in the telephone in such a way as to reproduce the original sounds.

The methods of telephoning with light hitherto used may be divided into two classes. In the first, the aim is to cause the speech to control the illuminating power of the source itself. For example, if the current in an electric arc can be controlled effectively by microphonic action, the light issuing from the arc may be expected to have the character desired. The second general method is to effect the control of the beam by causing the speech to interrupt the light, with the proper periodicity and amplitude, *after* it has left the source, the actual illuminating power of which remains constant.

Of these two modes, there is little doubt that the second is the more effective and useful. In the first place, it permits the use of the sun's light as the source, whereas, in the other method, artificial sources only can be used. This, it will be seen later, is of considerable importance. It is desirable, also, that the changes of intensity brought about by the speech should be made as great as possible. In the case of an arc controlled microphonically, however, even if the current oscillates from zero to its maximum value—which is unlikely the variations of light intensity must still be comparatively small at the frequencies in question. If we take the average frequency of speech sounds as about 500 per second, it means that the brightness of the arc must alternate between maximum and minimum every 1/500 second, during which time the actual variations of its temperature, and, therefore, of its brightness must be small. Speech would thus impose no more than a ripple of small amplitude upon the already powerful beam of light emitted from the arc. On the other hand, by controlling the beam after it has left a constant source, it is possible, particularly by the method about to be described, to guarantee that the fluctuation of the beam traverses the widest possible range.

Both methods have been used with a certain amount of success. In a patent specification of 1889, Graham Bell describes two devices falling under the latter class. In the first, the proposal is to allow the beam of light to pass in succession through two grids consisting of equal parallel strips alternately opaque and transparent. One of these is fixed in position, and the other is moved bodily, in a direction perpendicular to the strips, by the operation of a diaphragm to which it is rigidly attached, and on which speech sounds fall. The movements of the diaphragm may be expected, therefore, to control the obstruction to the beam of light in such a way that the intensity of the emergent beam varies in accordance with the speech sounds. The practical objection to this device is that, ordinarily, the movements of the diaphragm are so small that it would be most difficult, if not impossible, to make grids at once so light, so rigid and so fine as to fulfil the necessary conditions. Graham Bell does not, in fact, claim that this method has been actually used. His second device is much more sound from a practical point of view. It relies upon the fact that a vibrating diaphragm is continually altering its curvature; consequently, if polished, and interposed in a steady beam of light, it will give rise to a reflected beam which is of variable divergence. Although the total amount of light reflected is actually unaltered, the fraction of it incident at a distance upon a receiver, not large enough to include the whole beam, will have a value controlled by the

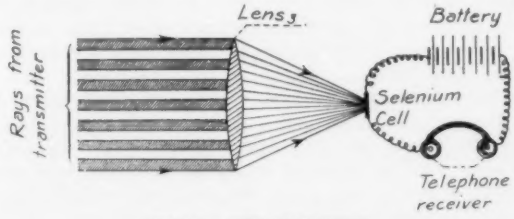


FIG. 2. THE RECEIVER

vibrations of the diaphragm. The objection in this case is that the diaphragm must be large in order to deal with a large quantity of light; for, if it is placed at a point where the beam has been concentrated to a focus, the effect of its changes of curvature upon the divergence of the beam is negligible. Further, from an acoustical point of view, it would be necessary for the diaphragm to be thin, and it would, therefore, not be suitable for adaptation as a mirror of good optical properties.

Mr. Rankine overcomes the difficulty caused by the weight of the grid, mentioned previously, by ingeniously substituting the *image* of a grid for the grid itself. To accomplish this an

optical system is arranged in which the light from the source is concentrated by a lens upon a small oscillating concave mirror, so arranged that, when in its position of equilibrium, it reflects the beam to a second lens by which it is again brought to a focus. A grid is placed between each lens and the mirror, with the result that a real image of the grid between the light source and the mirror is formed in the plane of the second grid.

If oscillations corresponding to human speech are now imparted to the mirror the image of the first grid, oscillating on the second grid, will give corresponding variations to the intensity of the emergent beam of light. A selenium cell, placed at the focus of this beam and connected to a telephone receiver and battery, will reproduce the sounds corresponding to the fluctuations of the light.

Several forms of apparatus are described. The transmitter may be constructed of a phonograph recorder, by attaching the mirror rigidly to the lever which ordinarily carries the needle; or a telephone receiver of the reed type, actuated by the variable current in a microphone, may be used instead. In another type of apparatus one grid is eliminated and the image of the single grid is superimposed on the grid itself, an arrangement which, in the author's opinion, will ultimately prove more efficient than that previously described.

Any source of light may be used, and the author used incandescent and arc lamps and sunlight successfully. The results obtained were encouraging. Conversation in both directions was carried on between stations 1½ miles apart, using a carbon arc for light, while the faintest whisper could be heard at this distance when sunlight was used. Using sunlight, Mr. Rankine estimates the range of the present apparatus to be approximately eight miles, but believes that this may be greatly extended by using amplifiers to magnify the currents in the receiving circuit.

AUSTRIAN ELECTRICAL INDUSTRIES DURING THE WAR.

A RECENTLY received issue of the Elektrotechnische Zeitschrift (v. 40, p. 322, 3 July, 1919) contains an account, by Emil Honigmann, of the Austrian electrical industry during the war. Little has hitherto appeared on this subject, as distinguished from the industry in Germany.

The war began at a time when economic and political conditions were reacting unfavorably on the industry and the first effect of hostilities was to paralyze it. The calling of the personnel to the colors, the disappearance of capital and the moratorium created an unprecedented situation and a dread of any movement. This situation lasted but a short time; demands for railway material and electrical machinery soon came from the army and soon afterwards the factories were arranged for munition manufacture.

Electrical factories turned especially to the manufacture of munitions, finishing shells, etc. There was also soon a large demand for shop equipment, dynamos, motors and apparatus of all kinds, and for wire and cables, telephones, telegraph instruments, and all the many varied electrical devices used by the engineering departments of the army and navy.

Other electrical undertakings were abandoned and every energy bent to meet military needs. Early in 1915, every shop was devoted to war manufactures and every lathe was busy. Soon the difficulties began to appear. Raw and intermediate materials began to be scarce, the best workmen were at the front and satisfactory substitutes were not easy to find. Electric power stations were busy as the shortage of petroleum increased the demand on them and more power was used.

During the summer of 1915 the copper shortage began to be felt and aluminum came into use. Substitutes cannot be introduced into manufacturing, however, as readily as into foods; their use requires changes in design, construction and operation. The difficulties, however, were gradually overcome. At the same time the cost of labor and material rose rapidly. Electrolytic copper rose over 220 per cent. between January, 1914, and October, 1915, sheet brass 200 per cent., sheet zinc 77 per cent. and tin over 200 per cent. Wages increased from 25 to 50 per cent. Manufacturing costs increased rapidly from other causes as well.

During 1916 and 1917 the industry followed the same path. New plants were built, in spite of soaring costs and the ever increasing shortage of materials. Careful research for substitute materials was undertaken. Every effort was made to bolster up financially weak concerns, prices were increased, and trade organizations formed.

In 1917 the food problem became acute and the factories were obliged to take up the rationing of their workers. After the invasion of Italy new supplies of material also became available and conditions were easier, but the peak was reached at the beginning of 1918. The long duration of the war, with its attendant breaking of morale and finance began to have its effect. Prices still increased, but no longer as rapidly as costs, and careful manufacturers reduced dividends and commenced a policy of economy.

In October, 1918, the armistice produced the catastrophe and the empire fell to pieces, carrying with it the industries of the country. Since that time the industry has stood still, with the outlook far from favorable, so far as the immediate future is concerned.

One technical effect of the shortage of material was the modernization of many old plants. A number of old direct-current installations were replaced by alternating-current distributing systems, to recover the greater amount of copper used in them. A considerable amount of lead was also recovered from the storage batteries with which many were equipped. In many cases the recovered metal practically paid the expense of the change.

EFFECT OF LIGHT ON THE EYE

THERE has long been an impression that yellow light is more agreeable to the eye than that containing chiefly the green and blue rays, and it is generally believed, for example, by many medical and technical men that the kerosene flame produces a more "restful" light than other illuminants, especially than incandescent solids. This supposition has been submitted to careful tests by C. E. Ferree and G. Rand, and the results have appeared in the Transactions of the Illuminating Engineering Society (v. 13, p. 50, and v. 14, p. 108).

The experiments have compared the kerosene flame with the light from the carbon incandescent lamp, the Mazda lamp, types B. C and C2, and with Welsbach mantles containing various amounts of ceria, and therefore varying in yellowness. The standard of comparison is the efficiency of the eye as determined by the ratio of time during which steadily observed type appears clear or blurred.

The results obtained from numerous careful, prolonged experiments indicate that there is some justification for this impression, as they indicate that the efficiency of the eye diminishes more rapidly with light from the metal filament than with that from kerosene, and decreasing yellowness in Welsbach mantles also diminishes this efficiency of the eye. The authors, however, are not yet prepared to state positively that yellow light is better than white, but merely that yellow is better than green.

BREAKAGE IN HIGH-TENSION INSULATORS.

THE *Electrotechnische Zeitschrift* has recently published (Nos. 16, 17, 18 and 24, 1919) an extensive report on the causes of failure in insulators for overhead transmission lines, by E. O. Meyer. The following abstract of the original communication, taken from the *Electrician*, 24 October, 1919, gives the main results obtained in the inquiry.

A transmission line was constructed in Kreuzwald between 1911 and 1914, consisting of 320 km. of line, carrying current at 65,000 volts. At first there were breakages, due largely to

accidental causes, mostly connected with transport and construction; but in the process of time, mostly in 1915 and 1916, the breakages increased considerably in number and caused numerous stoppages. At 65,000 volts, in bright dry weather, there is a marked hissing sound from an insulator; if it is defective, it gives either no sound at all, or a very strong extraordinary hiss. In either of these cases it ought to be changed without delay, to anticipate a possible breakdown. Records showed that in this case the cracks were exclusively on the upper part of the insulator, which consisted of three portions cemented together. There were always two characteristic cracks: the one goes radially in a plane through the axis of the insulator, tending to split it into symmetrical halves; the other goes somewhat in the form of a ring around the top.

Mechanical causes did not seem likely to produce the result. The binding wire might be loose and tend to hammer the insulator in rough weather; but this was not found to be the case, as the binding was nearly always tight on the cracked insulators; neither could the expansion of the pin cause the breakages, as it would tend to break the lower parts as well.

Electrical effects were examined. Naturally, the uppermost phase is most exposed to direct and indirect atmospheric effects. But records on the line in question showed that the disturbances were not at all confined to the uppermost phase, but were nearly equally distributed, though the phase affected by lightning was more generally the uppermost phase. It was thought possible that the insulators were not big enough for the pressure; but it so happened that, owing to accidental causes, certain long lengths of the line were worked for some months at 10,000 instead of 65,000, and the breakages continued as before.

It was suggested that as the cement dries it alters its electric conductivity, and consequently affects the distribution of the lines of force; but the author regards this suggestion as improbable. Air bubbles in the cement might give rise to glow discharges, and to very slight internal heating; but this would scarcely be likely to attack or burst porcelain. Peasley, in America, put forward the suggestion that an insulator might be injured if it were subjected to a high-frequency surge as well as to a voltage of low periodicity; but this is not proved.

The shape of the insulator is next examined, as being possibly a contributory cause. The author examined this matter in some detail, he finds no clue to the solution of the problem in hand. He also collected together in tabular form such figures as are available with regard to the technical properties of porcelain itself; but there is no definite agreement as to these figures, and some makers felt themselves not to be in a position to make any positive statement on the point.

It was next suggested that temperature effects might explain something. The author quotes a series of tests which he carried out on porcelain balls; these certainly cracked if the change of temperature was very marked, much more so than is likely to occur in practice; but generally speaking, the cracks were across a meridian, and this is not of the characteristic type noticed in insulators. There was no distinct proof that anything could be due to this cause; but it is possible that the temperature may affect the cement, and so injure the procelain indirectly. Records show that on the 65,000-volt line, to which this investigation had special reference, most of the breakages take place in summer, and not specially in thunderstorms, but in bright cloudless weather. Temperature, therefore, undoubtedly has some effect.

Thus, finally, there remains only the question of the cement. Portland cement is now mostly used, and Dr. Riepert says that cement expands slightly on setting, but the expansion and possible subsequent contraction depend on the conditions—*e.g.*, whether it sets under water or in the air. This is common to all cements, but a poor cement also "drives"—*i.e.*, it is liable to crack and destroy anything within which it is enclosed. This "driving" begins sooner if it hardens under water than if it sets in the air. Cement can be tested by making a small block and allowing it to set for one day in the air, and then for a month under water. It ought then to show no cracks on the top, though some "driving" cements will show cracks in three days. There are sometimes curvatures and cracks on the edges of the block. The cracks run mostly in the direction of the middle of the block and gape most at the edge; often they are connected with a network of fine cracks. These cracks must not be confused with those which are liable to form while it sets in air as it dries; the latter form irregular curved lines over the surface. The blocks, while setting ought to be protected from draughts and sunshine. Cements with more than 5 per cent of magnesia, if burnt till they sinter, do not show marked signs of "driving" till several years have expired. Cement must be kept moist during the first stage of hardening, and is liable to crack if the block is put into water too soon. The "driving" of the cement seems, in the view of many competent persons, to be the main cause of the characteristic cracking. Since the magnesia content is the determining factor in the "driving effect," several cements were chemically tested which were taken from insulators that had cracked, some of them after having been in use seven years. The results of these analyses are given. In no case was there 5 per cent. of magnesia, the figures actually being 1.04, 2.4, 2.79, 0, and 0.92 in the five cases respectively. The "driving" and expansion of the cement cannot be entirely avoided, and there are other points in connection with the cementing process which require careful attention. The cementing mixture must not be too dry, and the moisture must be evenly spread throughout the mass. In some cases the cemented joint has shown on fracture a very uneven distribution of the cement. Sometimes there is too much on the one side or on the top. If there is a thick layer of cement on the one side and a thin one on the other, the crack will take place on the thick side. It is, therefore, necessary to see that the design only allows for a thin layer of cement, which must be evenly distributed. According to the experts, cement takes two years to set fully, and this possibly helps to explain why the fractures only take place after several years. After it has set, cement becomes a rigid substance, which is almost entirely a non-conductor of heat.

Improvements in manufacture are, therefore, an urgent necessity. The cause of cracking lies in the cementing process by which the parts are joined together. The specification of the latest type for 65,000-volt insulators prescribes a maximum thickness for the cement layer of 2 mm. at the top and 3 mm. at the sides of the cylindrical surface. On 45,000-volt insulators the manufacturing process has become so exact that the thickness varies between 1.5 mm. and 2.5 mm. The parts to be cemented together must fit exactly in point of size, and must be sorted for this purpose. The choice of the cement, the character of any admixtures, the preparation of the cement paste, its moisture while setting, and the keeping of the insulators a sufficient time in store without disturbance—all these things need attention. A coat of lacquer on the surfaces to be cemented has been tried, but this is not likely to effect much, as shellac oxidises and becomes hard and inelastic. A sheet of lead foil has been tried, also cork insets and metallic plates; but these are all useless. Lately a coat of graphite paint 0.1 mm. to 0.3 mm. thick has been tried, and also a thin copper ring; but this idea seems likely to fail, inasmuch as this constitutes no sufficiently rigid connection. Experimentally it has been proved that a slight movement is possible with these semi-elastic joints; this is likely to prove fatal in everyday work. The copper foil is so delicate that it is often injured in the cementing process. Drawings are given of two modern types of high-tension insulator, with dimensions and test pressures; in these cases there is a kind of hemispherical joint between the various parts. No kind of elastic joint is used. If improvements on these lines can be made, the pin insulator will be preferable to the suspension type, which costs in all at least three times as much, apart altogether from the fact that the poles must be 5 ft. or 6 ft. longer.

Progress in Mining and Metallurgy

A Summary of Important Articles in Current Periodicals

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

PROPERTIES OF STANDARD OR STERLING SILVER.

STANDARD or sterling silver, which contains 92.5 per cent of silver and is the only silver alloy of industrial importance, derives its name from the fact that, from very early times, it has been the legal standard alloy for all British silver coinage and, so-called, silver plate. When the alloy is cast, there is a tendency for the silver to become concentrated in the middle of the ingot, but when proper precautions are taken the differences in composition in different parts of the ingot are not sufficient to interfere seirously with the application of the alloy to minting and to industrial purposes. They found the temperature of the metal in the crucible, when ready for casting, to be about 1,200° C., and that of the stream during pouring to be about 1,113° C. The best temperature for annealing, in works practice, had been found to be 670° C. for all-around work. The time varied according to the thickness of the sheet but, generally, annealing was complete in from 20 to 30 minutes. The maximum Brinell hardness of standard silver was about 183. The maximum tensile strength varied from 11 tons to 14 tons per square inch according to the method of casting.—*W. E. A. Smith* and *E. H. Turner*, in *The Engineer* (London), Oct. 10, 1919.

DRILLING AND PRODUCTION TECHNIQUE IN THE BAKU OIL FIELDS.

By ARTHUR KNAPP.

No OIL territory in the world has been so rich in large producing wells, in a comparatively small area, as the Baku field. Particularly is this true of the Bibi Eibat field, which formerly produced millions of "poods" of gusher, or as it is called in Russia, "fountain" oil. The Bibi Eibat and Balachany fields have been exhausted of gas and ruined by water, but the Surachany and Benegadi fields are still fountain territories and many outlying districts that have only been prospected produce rich fountains.

The method of controlling "fountains," or gushers, is the result of growth, along with the Russian system of drilling, where large diameters and riveted casing have been in vogue. The screw casing is seldom used except to exclude water. Formerly the method of finishing wells and the condition of the casing at the top of the well would not permit the use of gates, manifolds, and connections, as in standard methods elsewhere. The life of the flowing wells is very short, particularly those 10 in. (25 cm.) or more in diameter, which produce large quantities of sand and often flow for but a few days and are then a complete loss. More than 1,000,000 poods in 24 hr. have been claimed in several instances, but in no case was the flow for more than few days.

The oil sands of this district are free uncemented sands and vary in thickness from paper thin to a maximum of 10 ft. (3 m.). The sands are interlaid with strata of soft clay. In spite of this, the practice has been to drill into such sands and produce from the open hole without screen or liners. Sometimes the casing is set below the oil sand, but in this case holes from 2½ to 3 in. in diameter are drilled opposite the oil sand, which would not have the effect of a screen.

The Russian method of drilling makes use of steel poles to actuate the tools but differs from the Canadian system, which uses poles of wood or iron, in that a "free-fall" is used above the tools instead of the tools dropping with the rods. This free-fall picks up the tools at the bottom of the stroke and releases them at the top of the stroke, allowing them to fall free to the bottom of the hole. Thus the fall is limited to the length of the stroke of the walking beam and differs from the American cable tool system where the fall, due to the elasticity of the drilling cable, may be several times the stroke of the beam.

The Russian drilling machine is a slow ponderous machine, very heavy and very hard to handle, transport, and install. It cannot be said in reality that this machine drills, but eventually it manages to worry a hole into the ground.

The general character of the Russian method accounts for most of the slow progress, together with poor tools, material, and labor. Wells are usually drilled by contractors who are paid per linear foot on a sliding scale, depending on the depth. They are paid by the day while fishing and are not liable for casing lost.

FORGEABILITY OF IRON-NICKEL ALLOYS.

By T. D. YENSEN.

IN the investigation of the magnetic properties of iron-nickel alloys, it was found necessary, in order to make the alloys forgeable, or malleable, to add small quantities of some other element. Iron-nickel alloys have been known for nearly a century, but have been made in commercial quantities only since 1885. The chief difficulty in their development was that the "pure" alloys did not forge readily. The addition of small amounts of manganese, however, made the alloys forgeable. The present paper shows to what extent manganese is needed for various nickel contents and also what is the effect of other alloying elements on the forgeability.

The forgeability is given for the four conditions: Cold, black heat, dull red, and bright red. Cold means a temperature of 20° to 100° C.; black means any temperature below the appearance of redness, that is below 600°; dull means 600° to 900°; and bright, temperatures above 900°.

Up to 7 or 8 per cent nickel, the forgeability is fairly good at a dull red heat. The effect of silicon on the forgeability is very slight, if it has any. Aluminum, carbon, and magnesium have no beneficial effect upon the forgeability. Manganese, as was anticipated, makes the alloys forgeable. Of all the different elements tried, titanium has the most beneficial effect on the forgeability.

REVERBERATORY FURNACE FOR TREATING CONVERTER SLAG AT ANACONDA.

By FREDERICK LAIST AND H. J. MAGUIRE.

THE ore from the Butte mines of the Anaconda Company contains considerably less iron than is needed for the fluxing of the silica. As the losses in the concentrator were high, compared with the losses in the blast furnaces, it was found, by calculation, more profitable to send ores containing more than a given percentage of copper to the blast furnaces in spite of the higher costs of treatment.

With the introduction of the flotation process, it was found possible to maintain an average recovery, as concentrates, of 96 per cent. The cost of reverberatory smelting was materially decreased by the use of pulverized coal. These two changes in practice made the blast furnaces unable to compete with the reverberatory furnaces on a cost basis.

The amount of basic fluxing materials required for the smelting operations became small and the converter slag lost its former value as a blast-furnace flux. For this reason, a less expensive method of recovering the copper, silver, and gold contained in it than smelting in blast furnaces had to be found. It was not feasible to pour the slag into the regular reverberatory furnaces.

It seemed that the successful traetment of the converter slag would require the reduction of Fe_3O_4 contained therein to FeO. Silica would have to be furnished to combine with the FeO so as to produce a slag containing not less than 30 per cent silica. At the same time, iron sulfide would have to be furnished to combine with the particles of metallic copper and white metal and carry them into a comparatively low-grade matter. All of these reactions, it was thought, could be brought about by the addition of unroasted or partly roasted fine concentrates and fine siliceous ore. The experiments were carried out under the supervision of F. F. Frick, research engineer for the Anaconda Co., and gave reasonably satisfactory results.

The average cost for treating converter slag during the year 1918, after segregating the cost of all other material, and assuming this other material to have pursued its regular course through the smelter, was $0.6126 per ton. The cost per ton for the second six months of 1918 was $0.4648.

PETROLEUM RESOURCES OF GREAT BRITAIN.

By A. C. VEATCH

THE present work in Great Britain had its inception in 1914, when the outbreak of the war enabled the writer and his associates to carry out a long-deferred desire to see just what the numerous indications of petroleum in Great Britain really meant. Thanks to the great mass of fundamental geological information which the Geological Survey of Great Britain had collected and published, and particularly to the detail work carried out in certain of the coal fields, it was possible in a short time to present to Lord Cowdray the conclusion that the petroleum possibilities of the Midlands of England were of a most amazing and striking character. With the increase of the submarine menace, he offered to place the services of his firm and his petroleum staff at the disposal of the nation, free of cost, for carrying this work forward as a war measure. This was a gift made to the nation without any commitment of any kind on the part of the British Government to Lord Cowdray.

The midlands of England contain large areas of important oil lands, which, however, will not become of commercial importance for at least five years, because the ownership of the oil has become a political issue. In the center of England the Mountain limestone (Mississippian) is exposed along the axis of the Pennine fold. Like the similar carboniferous limestones in Kentucky and Missouri, it is cut by spar and lead veins but, unlike those, it contains numerous important seepages of petroleum.

The discovery well is located on a faulted dome at Hardstoft, Derbyshire, where none of the coal mines had found oil in the fault planes. It started in the coal measures, found wax in drilling through a fault, a commercial supply of gas in the Millstone grits, which was muddied off, and oil in the top of the limestone at a depth of 3,078 ft. (938 m.). This well has been flowing at the rate of 12 bbl. per day since June of this year, and is estimated to have a pumping capacity in excess of 50 bbl.

Two wells located on domes south of Hardstoft, both started in the coal measures, penetrated the Millstone grits without finding gas in any considerable quantities, showed a little oil in the top of the limestone, and are now drilling in the limestone, where they have encountered a little gas. The two wells that are being drilled in Scotland are in an entirely different category. They are merely "wildcat" wells, with a moderate chance of being successful.

The oil from the Hardstoft well has the following characteristics: Specific gravity, 0.823; sulphur, 0.26 per cent; gasoline, 7.5 per cent; kerosene, 39.0 per cent; wax, 6.0 per cent; gas oil, 20.0 per cent; lubricating oil, 30.0 per cent. The oil is particularly rich in very high-grade lubricants.

CHEMICAL WARFARE.

By Lieut. Col. AMOS A. FRIER.

CHEMICAL warfare is a complete science in itself. No other invention, since that of gunpowder, has made so great a change in warfare as gas. The air service is the only service that approaches it in the completeness of the change of methods of fighting. Today there are only four really distinct arms of the service; viz., the infantry, the artillery, aviation, and chemical warfare. All other forms of warfare are a combination of these.

No officer, however well trained in other duties under the War Department, can handle gas until especially trained in its use. It is the most universal of weapons and, as it drifts with the air, becomes the most difficult of all methods of warfare to avoid. No form of precaution heretofore used on land or sea is effective against it.

Considering its power, gas has no equal. Gas, used properly, will make the wearing of the mask a continuous affair for all troops within 2 to 5 miles of the front line, and in certain places, for many miles beyond. The reduction in physical vigor and, therefore the efficiency of an army forced at all times to wear masks, would amount to at least 25 per cent which is equivalent to disabling a quarter of a million men out of an army of a million. Gas, being heavier than air and yet carried with the air, with which it slowly mixes, rolls into depressions and dugouts and hangs among trees and rocks long after it has dissipated in the open. With it the sniper can be driven from his lair and countless American lives saved. Can any man afford, in the face of these facts, to say that America should give up gas?

If the United States must clean up Mexico or is forced to put down uprisings in the Philippines, in San Domingo, or any other place among peoples not thoroughly prepared with masks, the work can be done by using gas at a less expense and with far less loss of American lives than by any of all methods of warfare put together.

A FOREIGN OIL SUPPLY FOR THE UNITED STATES.

By GEORGE OTIS SMITH.

TWELVE years ago the Director of the United States Geological Survey addressed to the Secretary of the Interior a letter calling attention to the government's need for liquid fuel for naval use and pointing out that the rate of increase in demand was more rapid than the increase in production. This letter, in a way, inaugurated the policy of public oil-land withdrawals, which was well founded in its primary purpose of protecting the oil industry and highly desirable in its immediate effect of checking the over-development of that day in California. Unfortunately, however, through delays in legislation, this policy may be regarded now as having outlived both its extent and its usefulness. In 1908, the country's production of oil was 178,500,000 bbl., and there was a surplus above consumption of more than 20,000,000 bbl. available to go into storage. In 1918, the oil wells of the United States yielded 356,000,000 bbl., nearly twice the yield of 1908, but to meet the demands of the increased consumption more than 24,000,000 bbl., had to be drawn from storage.

Nor is this all of the brief comparison. In 1918, our excess of imports over exports of crude petroleum was nearly 33,000,000 bbl., whereas, in 1908, we exported 3,500,000 bbl., which was net, as we had begun to import Mexican oil. In this period, the annual fuel-oil consumption of the railroads alone has increased from 16,871,000 to 36,714,000 bbl., the annual gasoline production from 540,000,000 gal. to 3,500,000,000 gal.

This record may be taken not only as justifying the earlier appeal for Federal action, but as warranting deliberate attention to the oil problem of today.

The position of the United States, in regard to oil, can best be characterized as precarious. Using more than one-third of a billion barrels a year, we are drawing not only from the underground pools but also from storage, and both of these supplies are limited. In 1918 the contribution direct from our wells was 356,000,000 bbl., or more than one-twentieth of the amount estimated by the Survey geologists as the content of our underground reserve; we also drew from storage 24,000,000 bbl., or nearly one-fifth of what remains above ground. In a single decade, then, the consumption of fue loil by railroads has more than doubled; the consumption of gasoline has increased sevenfold. With the rapidly mounting cost of coal, the competitive field of fuel oil for steam use is expanding. We may lessen the increase in coal or oil consumption for generating power by harnessing the water powers of the country; but prime movers whether driven by steam or water, require lubrication.

A most serious aspect of our oil problem presents itself when we consider the entry of the United States as a real factor in the shipping of the world. Any nation that aspires to a large part in the world's commerce imposes upon itself an oil problem; for the future freedom of both the sea and the air will be defined in terms of oil supply.

A country-wide thrift campaign for saving this essential resource needs to be waged. Man power and oil ought to be conserved all along the line of production and consumption by better methods in the discovery, drilling, recovery, transportation, refining, and use of petroleum and its products.

The estimate by the United States Geological Survey of the oil remaining in the ground is, of necessity, subject to criticism as speculative, yet the excesses of unexpected yield in one region will largely be balanced by deficiencies in another. If happily the estimate of reserve proves too low, this unpredicted abundance would surely raise the consumption rate. On the whole it is fair to consider the official estimate of 6,500,000,000 bbl. as conservative and 8,000,000,000 as an improbable maximum. The difference between these two estimates of reserves represents only four years' supply, even at the present rate of consumption.

Two methods of handling the problem of a future oil supply suggest themselves; either reserve the domestic oil fields for American development and thus prevent foreign acquisition of what is needed at home; or, encourage our capital to enter foreign fields to assist in their development, thus insuring an additional supply of oil for our needs. The one method harks back to the "Chinese wall" period, the other expresses the "open door" policy. At present the United States Government follows neither method; the British Government has adopted both.

The British Admiralty led the way in its appreciation of the advantages of fuel oil, and the British Government has led the way in assuring to its nationals control of oil resources wherever found on British territory. Advantages that American capital may once have held in Trinidad and elsewhere in the British Empire are not now enjoyed and British enterprise is narrowing the field of opportunity in Mexico, South America, Mesopotamia and Africa.

RELATIONSHIP OF PHYSICAL AND CHEMICAL PROPERTIES OF COPPER.

By FRANK L. ANTISELL.

CERTAIN physical and chemical properties of copper are so intimately related that a change in variation of the physical properties indicates a certain chemical change. The standard specifications of copper of the American Society for Testing Materials are based upon physical characteristics with one exception, namely, the copper contents. Certain phenomena of the surface indicate the adaptability of the metal for forging or rolling. The writer believes that it is much simpler to produce shapes that are metallurgically correct than those that are mechanically satisfactory.

The appearance of the surface of the copper when cooled is considered as to its "pitch," or the general contour of the surface, and the "set," or the detail appearance of the surface of the shape. The set of the copper is, in a very large measure, directly related to the pitch; and so intimately are these characteristics connected that they are often used as synonymous terms by the refiner when he is speaking of well-refined copper. Oxygen is often spoken of as a medicine for copper, it being used to regulate the pitch.

The general physical properties of copper change in a marked manner with the increase of sulphur. An increase in the sulphur contents affects the number of bends in a very much greater ratio than does oxygen.

Reasons for rejecting refined copper on physical examination are: Low pitch; overpoling; cold sets; spewing; shot; fish (slivers of foreign copper, as the fins from the pouring ladle, etc.); holes of several characters, as water holes, shake holes, shrink holes, gas holes, spew holes, general porosity; foreign substances, such as charcoal, bone ash, dirt, etc.; splashes; fins; cracks; large set marks; water bursts; ridges on surface; shapes cast in rough molds; wrong dimensions; and collective defects.

GEOLOGIC DISTILLATION OF PETROLEUM.

By BAILEY WILLIS.

IN 1882, Peckham put forward a provisional hypothesis to account for the distillation of petroleum. He did not formally state the hypthesis, but in a discussion of facts drawn from many fields he made it clear that he regarded petroleum, and especially the petroleum of the Pennsylvania fields, as a "fractional distillate produced under high pressure and consequently at a comparatively high temperature."

The object of this paper is to test Peckham's hypothesis and the contributions to it made by White and Johnson by considering the geologic activities of the Appalachian province in the light of present-day knowledge. The presence of oil and gas in the Permian geosyncline is accounted for by the driving force of the excessive gas pressure due to distillation in the folded zones east of that basin. The preponderance of oil in the western part of the oil fields and the very great preponderance of gas in the eastern part follow from the order of distillation in the course of movements which increased gradually in intensity in each fold; first oil and then gas in quantity, in the order of distillation and in progress up the monocline from east to west. The quality of the oil and the large proportion of gas follow from repeated distillation and migration through long distances.

The absence of salt water from the dry sands in the deeper part of the geosyncline does not find any explanation in this general hypothesis. It is, however, a condition which may reasonably be attributed to migration at a later date, the salt water rising along the limbs of the geosyncline as the gas pressures at higher levels diminished through leakage, erosion, and other superficial factors. If so, the original condition of accumulation would not bear upon the present distribution of the salt water. We may conclude, then, that Peckham's hypothesis of geodynamic distillation of petroleum meets the facts in the Appalachian field.

A study of American and European oil fields along the lines of Peckham's theory obliges us to recognize a great diversity of conditions under which petroleum may be distilled and under which it may migrate. Nowhere, so far as the writer knows, is there an exact parallel to Appalachian conditions. This was to be expected, for the petroleums of the Appalachian fields present peculiar characteristics, and the Appalachian folding, was almost unique in respect to the character and dynamics of deformation.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

DYE DEVELOPMENTS.

In a recent issue of the *Wall Street Journal* the statement is made that one of the dye manufacturing concerns has already lost a very large sum as a result of its effort to give America a domestic dye industry. The money expended cannot be considered lost if it leads eventually to the establishment of a dye manufacturing business, for it is but a fraction of what must be spent in developing new colors, perfecting old ones, and carrying on a broad systematic program of research. Indeed, the statement is made that one concern invested 800,000 in perfecting a single dye stuff. The question therefore continues to be not what it will cost, but whether the country is prepared to give the kind of support to such enterprise which justifies such large expenditures and attracts the necessary capital at the present stage of development.

In a bulletin issued by the American Chemical Society, Dr. Charles H. Herty, who has just returned from Paris where he was sent with the approval of President Wilson to make certain investigations relative to the dye trade, makes the statement that Germany stands ready again to seize the dye trade of the world and to stifle American competition unless adequate legislation is provided. As has been frequently pointed out 75% to 80% of the necessary dyes are available here. Four per cent of the missing dyes commonly called "vat" dyes are particularly desired by the cotton trade, and it is understood that Dr. Herty was sent abroad to determine what could be done to secure enough of these dyes for the use of American manufacturers until American dye stuffs of this type are ready and on conditions that would not pledge the American consumer to a long-time contract.

According to the terms of the peace treaty, 40,000 tons of German dyes, valued at about $70,000,000, had been impounded, and in addition to this quantity, some 6,500 tons had been produced from the daily output, and these the Germans had for free sale under license from the Rhineland Commission. American consumers are permitted to import a portion of these dyes. To quote Dr. Herty: "The threat to the American dye interests, that is, both consumers and producers, lies in the fact that until American manufacturers can supply all of America's needs, Germany can charge extortionate prices for these dyes which we do not manufacture. She is manufacturing dyes on a large scale and because of the present low value of the mark, she will be able to underbid the American dye producer in an open competitive market. The only solution of this problem is legislation by Congress and the introduction of a license system until the American manufacturers are able to supply all our needs and to meet the competition of Germany."

The great Badische plant had smoke issuing from twelve of its fourteen chimneys on October 30th and the dye works on the banks of the Rhine, which represent the greatest factories in Germany, are producing dyes in large quantities. The directors of the Badische plant are confident that they are going to get back their old American business through the medium of their former agents, and state that the lines have already broken and that they have in hand orders from individual consumers in the United States with the authority from the United States Government to ship supplies through their American agents to the consumer.

To again quote Dr. Herty: "The same confidence characterizes the industrial German as had been recorded by the military German in his first advance through Belgium, the same utter contempt shown of American capacity to do things as was revealed during 1917. But 1918 showed that the German had missed his guess and I make the prediction that he has missed it again. Only one thing is needed to insure the correctness of that prediction, namely that the mass of our people understand just what the situation is. Such an understanding will reflect itself in sympathetic protective legislation, and time will do the rest, for the American chemist needs only time to forge the missing links in the chain of a complete self-sustained dye industry."

It would seem therefore that the industrial war is on and we will do well to consider the resources of our antagonist. Germany faces a winter in which the coal supply may become a very serious factor. Transportation problems confront her and the German seems worried over the situation created by the seizure of those patents through which he had for so many years successfully throttled American industry, although he agreed in signing the treaty of peace that these seizures were valid. But notwithstanding these handicaps, the German dye manufacturer is strong today. He has been able to keep the personnel of his plants intact, his plants are in prime condition and even greater than before the war, he has the determination to regain his markets, and it would be an error to underestimate his ability and fighting strength.

Twenty years ago a Swiss professor predicted that some day the synthetic dye industry would flourish in the United States because it is the natural home of that industry, and it appears that time and needful legislation can combine to fulfill the prophecy.

Dr. Herty stated that arrangements had already been made to have sufficient vat dyes in this country by the first of next year to meet the immediate requirements of the American manufacturers and meanwhile ample preparations are being made by American producers to eventually cover American needs. But during this preliminary stage favorable legislation is absolutely essential and even those manufacturers who have always contended for low tariff or free trade principles, seem convinced that the only safe way to insure to America the one industry which above all others should result from the world war is by the enactment into law of the legislation now in Congress.

INDUSTRIAL POISONING.

In the *Journal of Industrial Hygiene*, Dr. Alice Hamilton of the United States Bureau of Labor Statistics, and Assistant Professor of Industrial Medicine at Harvard Medical School, discusses industrial poisoning by compounds of the aromatic series. The study reported embraces benzene and benzene derivatives, nitro-benzene, aniline, and dye manufacture.

The danger from contact with benzene, which is absorbed in the higher boiling oils, during the coking process, which are afterwards subjected to fractional distillation, begins in the distilling house, and while ordinarily there is no danger of industrial poisoning, any accidents which result in a spill or which necessitates repair work, are attended with much danger. Dr. Hamilton cites the case of a man who was drawing off water from the bottom of the benzene settling tanks. To do this he had to stoop under the tanks and while he was supposed to close the valve as soon as benzene began to flow, he apparently was slow in doing this and the fumes of benzene began to escape. Becoming dazed, he started to leave without turning off the benzene, but collapsed on the floor. Two men went to his rescue, but in carrying him up stairs one of them was overcome, fell and broke his neck. The workman was afterward revived.

Since benzene is used in so many industries, for example, as a solvent for rubber, in the paint and varnish trade, in coal tar paint, and as a raw material for making phenol and many intermediates, it is well to become acquainted with its effects. "In benzene intoxication the brain and spinal cord contain relatively more of the poison than any other structures, probably because of the great solubility of benzene in fats and fat-like bodies, such as the lipoids of the nervous system. The effect on the blood is marked and characteristic. There is an anaemia of the aplastic type and a great diminution of the white corpuscles. Capillary hemorrhages under the skin and mucous membranes are so common that the Germans call this form of poisoning "Blutfleckenkrankheit."

The action of the nitro and amido derivatives of benzene, used principally in the production of dyes, perfumes, drugs, and explosives, resembles that of benzene itself, although they do not produce the same effect on the blood cells. Mononitrobenzene is regarded as distinctly more dangerous than aniline, although there is not nearly so much poisoning from nitrobenzene because the work does not involve so much exposure as in the case of aniline. However, when it does occur it is much more likely to be fatal or to produce a longer period of disability than does aniline.

One of the symptoms of aniline and nitrobenzene poisoning is the deep blue color of lips and tongue with headache, slight dizziness, and difficulty in swallowing. The rubber industry used to be the greatest source of aniline poisoning, but the dye industry has displaced it. Aniline has been largely replaced by a solid aniline formaldehyde in rubber compounding and this does not appear to cause industrial poisoning.

The production of dyes on the present large scale presents another interesting field of investigation, for not only are benzene, nitrobenzene, and aniline used in great quantity, but there are a great number of derivatives, some of which may have a toxic action on the skin, the central nervous system, or the blood, or all three. The toxicity of the substances employed depends somewhat upon their physical condition, that is, whether solid or liquid, and to what extent they are volatile. In some instances the degree of toxicity can be estimated from their chemical content, for it is known that the entrance of chlorine into a fatty compound may be expected to increase its toxicity, but the benzene series appears to be little, if any, affected by the entrance of chlorine. Nitration, however, produces a decidedly poisonous product, that is, nitrobenzene and nitrochlorbenzene are much more poisonous than benzene and chlorbenzene. Sulphonation renders a compound non-toxic. For example, as soon as aniline is sulphonated it ceases to be troublesome. The introduction of an alkyl group lessens toxicity, dimethylaniline being less poisonous than aniline, while the HO group renders all members of the benzene series more poisonous. The same group changes alcohols to harmless glycols and glycerols.

Doubtless with the continued development of our chemical industry, the extent to which industrial poisoning is studied will naturally increase to the direct benefit of those engaged.

CHEMISTS' FIRST AID TREATMENT.

DR. PAUL N. LEACH has contributed a valuable series of articles on this subject to *the Chicago Chemical Bulletin* which has now reprinted them in the form of a pamphlet. In many chemical plants the chemist is regarded as the proper person to administer first aid treatment in the absence of a physician, and the difficulty which some people experience in distinguishing between the training of a pharmacist and a chemist may be in a measure responsible for that condition. The average chemist is not qualified to diagnose and consequently cannot efficietly administer treatment. He is unfamiliar with the action of most drugs, may not be familiar with bacteriology and the necessity for complete sterilization of instruments and materials used, and altogether should not be expected to perform the sort of work which a nurse or other properly trained person might. However, the chemist will continue to be called upon for aid and the pamphlet in question therefore will be of great assistance to him.

The emergency treatment of burns, abrasions, bruises, antidotes for poisons, particularly those of a chemical nature, and the proper course of procedure in the treatment of internal conditions is given.

FOOD AND NUTRITION.

A COMMITTEE on Food and Nutrition has been formed under the Division of Biology and Agriculture of the National Research Council, the objects being:

(1) To promote scientific research upon the nutrition of men and of animals, especially animals of agricultural importance, and to bring about closer relations between the two fields of work.

(2) To promote the study of the economic aspects of nutrition, that is, the study of national and international as distinguished from personal nutrition.

(3) Pending the possible establishment of a National Institute of Nutrition, to act as an unofficial clearing house for existing research institutions and to promote and coördinate both American and foreign research.

(4) To promote sane and authoritative extension and propaganda work in the interest of better nutrition.

The methods to be employed in the proposed studies of course differ with the subjects in hand, but coöperation with all existing agencies is very necessary and the first work will be the preparation of a broad program of research in both human and animal nutrition, emphasizing especially the gaps in our present knowledge, with the suggestion of problems of the most immediate importance.

Some of the questions in animal nutrition which are most significant have been arranged by Dr. E. B. Forbes, Chief of the Department of Nutrition, Ohio Agricultural Experiment Station, and a member of the committee, as follows:

(1) The influence of varying proportions of grain to roughage on the rate and character of the growing of cattle.

(2) The influence of the rate of growth on the character of the increase in cattle and swine, that is, the point should be determined at which the protein increase reaches its maximum.

(3) The influence of fertilizers applied to pastures on the skeletal development of calves and colts pastured thereon.

(4) The feeding and management of swine, with reference to the specific effects of feeds, especially of peanuts, on the chemical composition and physical constants of the body fat.

(5) Methods of utilization of the solids of butter, milk and whey.

(6) The development of a system of selective improvement of meat animals based upon the records of efficiency in the utilization of food.

There are many other questions of equal importance and those contemplated in studies relative to human nutrition form an equally large field for intensive research. Studies of this character initiated at this time and consistently sustained can be expected to provide data which is essential in considering our present economic problems in times of peace as well as of those of future wars in which foods may be expected to again play a dominating part.

COTTON LINTERS.

WHILE there is a comparative shortage of long staple cotton due to the inroads of the boll weevil and the new demands, estimated to be equivalent to 500,000 bales annually for cord tires alone in this country, there is an excess of short fibers and particularly of cotton linters.

Before the war about fifty pounds of linters were removed from each ton of cotton seed, but the war time need for cellulose, to be used in producing nitrocellulose, greatly increased the amount of linters produced per ton of seed and the Government finally stipulated a quantity which would be considered good practice. Now that the need for nitrocellu-

lose has diminished, there is a large surplus which normally would go to waste and we have therefore another problem for the chemist.

The Forest Products Laboratory has demonstrated that a good grade of paper can be made from this material and the pulp which could be supplied from this source would amount to many thousands of tons annually. The paper which has been produced is of a quality which would compete with or at least supplement the ordinary grades of rag stock paper and could probably be produced at an attractive price. This is especially true at this time when there appears to be a world shortage of rags for paper stock. Normally the United States is a large importer of rags from Europe, but the scarcity of fibers there and lack of transportation has curtailed this source, and in the interim it is hoped that a satisfactory method can be worked out for using what would otherwise be wasted, thus adding another item to the list of those on which the United States is self-contained.

The campaign to exterminate the cotton boll weevil continues with some encouragement through the use of calcium arsenate in various parts of the cotton belt, particularly in Louisiana. While it has been feared that the dusting of the plant with this poison at sufficiently frequent intervals to be effective would be considered a large item of expense, there are planters who testify that the actual expense is wholly justified and, of course, if the difference is between an acre which produces nothing due to weevil infection, and an acre which has been dusted and then yields a bale of cotton, a large cost can be justified.

The experiments have not been finished, but will be given continuous support. It is believed that the death of the weevil comes from poison present when he drinks the dew which has come in contact with the calcium arsenate.

CHEMICAL WORK AT THE FOREST PRODUCTS LABORATORY.

THIS laboratory is maintained by the United States Forest Service in coöperation with the University of Wisconsin and at the present time the station numbers about two hundred. The work is going forward under five sections, namely, Derived Products, Preservation, Pulp and Paper, Timber Mechanics, and Timber Physics. The equipment is unique, although not as extensive as some of the enthusiasas would like to have it.

Under Derived Products chemical studies of many kinds are made on naval stores, hardwood and soft wood, distillation products and processes, the manufacture of ethyl alcohol from wood, the analysis of wood preservatives, investigations of extraction processes and products, and similar studies.

Preservation of wood against fire and decay, the development of glues of various types for ply work and joint work, the perfection of specifications and processes for aircraft propeller manufacture, and the study of specifications and processes of manufacture of ply wood, constitute the principal activities of the Section on Preservation. In the preservation of wood, particularly railroad ties, against decay, zinc chloride plays a very important part and the question of the rapidity with which zinc is removed from the tie by leeching is a very pertinent one. The work done on this subject indicates that the presence of even comparatively large amounts of zinc in treated material does not necessarily mean that the wood is protected against decay, unless a sufficient amount of acid is also shown to be present. Unfortunately, our present methods make it possible for the chloride radical to be drawn from the wood by leeching faster than the zinc radical. Much of the work that has been done on the glues and ply wood is of importance to the veneer and furniture manufacturers and consequently is being continued for that purpose, if for no other.

The Section on Pulp and Paper carries on studies in all phases of pulp and paper manufacture, including investigations into the availability of various American woods for pulp purposes.

The Timber Mechanics Section, as the name implies, tests the mechanical properties of wood, studies the effect of defects upon its strength, the development of built-up construction, the improvement of shipping containers of all kinds, the effects of preservatives, kiln drying and other processes upon the properties of wood.

Under Timber Physics there is placed the study of the fundamental principles of the drying of wood, the development of commercial drying methods, and the determination of proper drying schedules of all American woods of importance.

The results of the laboratory's work are made available to the public through the publication of progress reports and final conclusions, supported by necessary data as rapidly as study upon the various phases of the problems can be completed.

BRITISH RESEARCH ASSOCIATIONS.

THE British Science Guild, 199 Piccadilly, W. 1, has brought out an interesting volume entitled "British Scientific Projects Exhibition, July 1 to August 5." The war work at universities and other institutions constitutes one chapter; that done in the laboratories of fourteen industrial establishments another; the third describes the progress of the formation of industrial research associations; the fourth lists an interesting collection of scientific and technical books; and the remainder of the volume is given over to a detailed description of the exhibits.

The research associations are of perhaps the most interest to American readers. As has been pointed out previously, they are formed under the Department of Scientific and Industrial Research of the Government, which has at its disposal a fund of one million pounds with which to meet the Government's share in the research work of these associations on a pound for pound basis. Eight of these associations have been incorporated, namely, boot, shoe, and allied trades; cotton; sugar; motor and allied manufacturers; photographic; Portland cement; woolen and worsted industry; and scientific instrument industry.

A like number have been approved, not licensed as yet. These cover India rubber; iron manufacturers; musical insruments; Scottish shale oil; linen; glass; non-ferrous metals; and chocolate, cocoa and jam.

Arrangements for similar associations to cover aircraft and refractory materials are nearing completion, while seven other industries are engaged in drafting articles of association. The latter are: silk; pottery; leather; laundry; master bakers and confectioners; engineering and shipbuilding, and those interested in the lighter manufacturing processes on metals.

As an indication of the work covered by such associations, the following quotation is made from the prospectus of the British Research Association for the Woolen and Worsted Industries:

"The object of the association is to establish, in coöperation with the Government Department of Scientific and Industrial Research, a national scheme for the scientific investigation, either by its own officers or by the universities, technical schools and other institutions, of the problems arising in the woolen and worsted industries, and to encourage and improve the technical education of persons who are or may be engaged in the industries."

The association has published an interesting pamphlet entitled "Scientific Research in Relation to the Woolen and Worsted Industries," in which emphasis is placed upon the objects of research, the methods for research, the cost which is based upon the capital stock of the contributing firms, and the effect of research upon industry. We quote from this last chapter:

"There is first of all the direct effect. A full knowledge, widespread through the industry, of the principles underlying

works and mill practice will enable us to look forward to the future without dread, to meet the vicissitudes of fortune, and to 'greet the unseen with a cheer.' Surely this will be no small gain. It should be emphasized that improvement in machinery and the introduction of more scientific processes are not likely to have the effect of diminishing the number of persons engaged in a well-organized industry. Carlyle pointed out long ago that in his day the number of bare backs was greater than the number of shirts available to cover them, and this is still true. In the language of the economist, the demand for clothing is not yet satisfied. Every improvement in the method of producing clothing will have one of two results: either it makes the goods more cheaply or it makes them better. In either case both labor and capital, to use the common terms, are likely to benefit.

"There are other indirect gains. . . . An industry conducted on scientific lines attracts a better type of worker. . . . Everyone who begins to have experience in industrial research at once looks at the industry from a new standpoint. . . . What they have looked upon as a daily round of mechanical operations pursued solely for the sake of making a living, is in fact an entrancing subject of study. What man is more fortunate than he who is daily absorbed in an occupation in which he has an interest? This applies both to employers and employes."

BRITISH ENGINEERING STANDARDS ASSOCIATION SPECIFICATIONS.

THE Secretary of the Canadian Engineering Standards Association, Ottawa, announces that some of the publications of the British Association are now for sale at their office. These publications include: An Interim Memorandum on French Metric Screw Threads for Aircraft Purposes; British Standard Tables of Pipe Flanges; Specifications for Structural Steel; British Standard Pipe Threads for Iron or Steel Pipes and Tubes; Specifications for Electricity Meters; Specifications for Cast-iron Spigot and Socket Flue or Smoke Pipes; Standard Rules for Electric Machinery; Report on British Standard Fine Screw Threads and their Tolerances; and the following sets of specifications: for cast-iron pipes, for hydraulic power, for keys and key ways, for sizes of broken stone and chippings, for salt glazed ware pipes, for charging plug and socket, for vehicles run by electric secondary batteries, wrought steel for automobiles, starters for electric motors and for electric cut-outs for low pressure type "O." There is further a report on the British standard dimensions for spark plugs, for internal combustion engines, a report on standard dimensions of wheel rims and tire bands for solid rubber tires for automobiles, British standard nomenclature of tars, pitches, bitumens, and asphalts, when used for road purposes, and British standard specifications for tar and pitch for road purposes.

WELDING THE SHIPS.

THE speed with which the German ships in American ports were prepared for trans-Atlantic duty is not to be looked upon as proof that the damage done was inconsiderable, but due to the high degree of skill attained in welding operations in this country, and to the fact that the German, in his customary methodical manner, carried out his orders so that the damage on each ship was essentially identical. Under these circumstances each ship did not present an entirely new problem, but the work was made easier and could be done with greater rapidity because the experience gained on one job fitted exactly into the requirements on the next.

Welding has become a fine art and chemistry shares in its present perfection. Modern metal compositions require high temperatures and the masses of metals used in some repairs are quite beyond what was considered possible but a few years ago.

In some instances the intense heat of the oxyhydrogen flame answers, but more recently the oxyacetylene torch has been preferred where a welding over comparatively small areas is required. The well-known thermit process where a chemical reaction both produces the required temperature and supplies the molten metal, has held first place almost undisputed in large scale repairs.

In the fabrication of steel ships electric welding proved to be of the utmost importance, helping to accomplish what would otherwise have been impossible. The American Bureau of Welding has taken an active part in this work and has directed much of the research on electric welding methods.

In aluminum welding, where large holes are to be filled, a surface of galvanized iron is sometimes provided to act as a chilling agent, causing the filler to cool and harden prematurely, thereby preventing it from contracting after the weld is finished. Galvanized iron is well suited to the purpose, since it peels away from the aluminum with ease after the weld has been finished and cooled. The welding of aluminum requires great skill, one of the difficulties to be overcome being the oxide film which forms rapidly on molten aluminum. A flux has proven its worth in preventing the formation of this film, thus allowing the aluminum to run together and forming a suitable weld. Before the flux came into general use for aluminum welding, it was almost impossible to build up the parts as desired, but this is now readily accomplished.

Spot welding has already taken the place of riveting for a great deal of fabricated material, especially sheet metal work.

NEW METHOD OF CHEMICAL ANALYSIS.

A METHOD of analysis is described by A. W. Hull in the *Journal of the American Chemical Society*, based on Debye and Scherrer's X-ray spectroscopy of so-called amorphous substances. In this method X-rays, after passing through suitable absorbing screens to render the beam homogenous, and through two suitable slits, are allowed to fall on a small cylindrical tube containing the powdered substance to be analysed. The "reflected" X-rays are received on a cylindrical photographic film. By comparing with similar photographs of known elements and compounds the photographic record obtained in this way, it is possible to distinguish the constituent compounds in the unknown powder.—From *Science Abstracts.*

INFLUENCE OF THE AGE OF THE COW ON THE COMPOSITION AND PROPERTIES OF MILK AND MILK FAT.

DATA obtained from the records of the Jersey, Holstein, and Ayrshire herds kept at the Missouri station show that the average variation in the percentage of milk fat from year to year is not large, with Jerseys the percentage of fat rising slightly in the second or third lactation period and then declining slowly as age progressed, while with the two other breeds the highest percentage of fat generally occurred in the first lactation period the curve then gradually declining. The milk of cows from 11 to 19 years old showed no abnormalities in physical or chemical constituents, and butter made from a cow 19 years old and in her thirteenth lactation period "was pronounced to be of excellent quality, and kept for a period of three months at a temperature of 8° to 10° without showing any marked deterioration."—From *Chemical Abstracts.*

GLAUBER'S SALT IN SIBERIAN LAKES.

THE following is an estimate of supplies of precipitated Glauber's salt in some of the Siberian lakes: (1) The Great Marmyshansk Lake, 144,000,000 poods (2,600,000 short tons) of crystalline salt ($Na_2SO_4 10H_2O$) and 22,000,000 poods (397,210 short tons) of evaporated Glauber's salt; (2) Little Marmyshansk Lake, 25,000,000 poods (451,400 short tons) of crystalline salt; (3) Lake Tuskal (Minusinsk district)—up to 100,000,000 poods (1,805,500 tons) of crystalline salt; (4) Lake Varche (Minusinsk district)—up to 100,000,000 poods (1,805,500 tons) of precipitated crystaline salt and an enormous quantity of Glauber's salt in solution.—From *Commerce Reports.*

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

INTRODUCTION

THE readers of the SCIENTIFIC AMERICAN MONTHLY are probably better informed than the majority of people concerning the work done by the Bureau of Standards at Washington, but, even in their case, a short statement of the very broad field of scientific research covered by the activities of that Bureau may be of interst.

The usual idea of a standardizing institution seems to be that of a Bureau concerning itself with the comparison of weights and measures. Such was, in fact, the original work of this character undertaken in the United States, and from it the present Bureau of Standards has grown. The importance of exact fundamental standards was recognized in the earliest times, and probably dates from the beginning of civilization itself. Certain recommendatons concerning the establishment of standard weghts and measures were made at the time of the founding of our present government. Little however, was actually accomplished in the United States until the founding of the present National Bureau of Standards by an act of Congress in 1901.

Standardization, as understood at present, includes much more than the standardization of weights and measures, and it will give the reader some idea of the great variety of the work comprehended by this term to list the various kinds of standards with which the Bureau deals. These include: Standards of measurement, such as units of length, mass, and time; physical constants, as an example of which may be mentioned the latent heat of vaporization of water; standards of quality, which are concerned mainly with the specification of materials; standards of performance, such as the ratings given to engines, electrical apparatus, instruments, etc., and standards of practice, among which may be mentioned the specification of requirements for gas and electric service in our cities.

Work in connection with each of these standards requires the employment of a large corps of experts and calls into requisition all of our knowledge in the fields of physics, chemistry, and engineering. The organization of the Bureau is based upon the different kinds of work which it performs rather than upon the various kinds of standards. Its scientific work is divided into nine divisions, as follows: electricity, weights and measures, heat and thermometry, optics, chemistry, mechanical appliances, structural and miscellaneous materials, metallurgy, and ceramics.

From time to time, the Bureau will endeavor to supply certain notes on current researches which will be of interest to the readers of this journal. Those submitted this month are representative of the work now being carried on and in which the Bureau is coöperating with the various industries.

INVESTIGATION OF STRESSES IN REINFORCED CONCRETE FLOORS.

The use of reinforced concrete and tile for the construction of floors in large buildings has become very common of late years, and with the increasing use of these floors, it is essential to determine accurately the stresses to which they are subjected when called upon to withstand heavy loads. The theory of the behavior of such types of construction is not at present completely understood. The load upon any panel affects not only that panel, but all the surrounding panels, and the interactions of members thus developed is so complicated as almost to defy analysis. This makes it necessary to base designs largely upon empirical formulae, arrived at as the result of tests. Certain properties of the materials used enable the engineer to determine with a fair degree of accuracy the stresses to which the floor is subjected under various conditions of load. Materials under tension stretch or elongate, while those subjected to compression become shorter, and this change in length has been established for various materials. Therefore, if the elongation or shortening of the materials in a reinforced concrete floor have been measured, the amount of tension and compression in the materials may be calculated. In such a problem, it is assumed that the steel reinforcement carries all the tension while the concrete withstands the compression.

Since the steel reinforcement is embedded in the concrete, holes are drilled in the concrete a certain distance apart exposing the steel reinforcing bar for the purpose of making measurements, and with a very fine drill two holes are then made in the bar itself. The distance between these holes is approximately the desired gage length, say 8 inches. Similarly, for the purpose of measuring the compression, holes are drilled in the concrete about 8 inches apart and steel plugs inserted. In these plugs the very small holes for the instrument are drilled, as was the case with the reinforcement bar. We have just stated that these gage holes are made a specified distance apart; this distance is approximately equal to the zero position of two points on an instrument known as the strain gage. The strain gage is made up of a fixed point and a movable point pivoted to a metal frame. The movable point actuates through multiplying levers a hand on a graduated dial. A change in length of .0001 inch in the gage length may be thus detected.

The usual way of conducting a test of a concrete and tile floor is to arrange the desired gage openings in the steel and concrete at all points at which the stresses are to be determined. The strain gage readings are then taken and recorded on the data sheet when the floor is subjected to no load. Of course, if the holes in the steel and concrete had been drilled with absolute accuracy, they would all be exactly 8 inches apart, and there would be no need of taking a set of zero readings. Such a case never occurs in practice. The floor is then loaded in any desired way, with cement or other material and the measurements with the strain gage repeated. These will show a difference in length, both in the steel and concrete; the difference amounting to the total elongation or shortening in the gage length of 8 inches. The unit change in length will be this total change divided by the gage length. It is the usual practice to apply the load to the floor in small increments, so that when the data are worked up, curves may be drawn showing the deformations at different percentages of the total load. After the maximum load has been applied, this may be removed and zero readings again taken to show whether the material has received any permanent deformation. Sometimes, still another set of readings is taken several days after the removal of the load, as the material may recover very gradually. The accuracy of the readings obtained with a strain gage depends to a great extent upon the experience and skill of the operator, and one man should take all of a given set of readings during one test. Having obtained the readings, it still may not appear quite clear how the stresses in the materials can be calculated. The explanation, however, is simple. Experiments have shown how much a steel of given quality and cross section will elongate under different loads. The same applies to the compression of concrete. Knowing the lengthening and shortening, we are able to figure the unit stress at that time.

The deflection of the floor in a vertical direction under various loads is determined by measurements between points

on the floor slab under test and other points directly above or below them.

The Bureau of Standards has recently undertaken one of the largest tests of this type of floor so far carried on. The work is being conducted on a large test slab recently erected for a large manufacturing company located in Ohio. The floor slab which is to be tested is built of reinforced hollow tiles with concrete ribs between them and a two-way system of reinforcement. In this construction, the steel reinforcement is placed sixteen inches on centers, in each of the two directions parallel to the edges of the panel. In the center of each of the sixteen inch squares formed by the intersection of the reinforcement bars is placed a hollow tile, 12 inches square, of a depth equal to the nominal thickness of the floor panel. In the present case, six-cell hollow tiles, 6 inches in depth, are used. After these tiles are set in position, the whole area is filled with concrete flush with the tops of the tiles. The adhesion between the tiles and concrete is depended upon to give unity of action.

The first slab, as built for the above firm, consists of eighteen panels. Six panels are each 16′ × 16′; six are 16′ × 19′ — 3″, and six are 16′ × 22′ — 6″. Each group contains one panel having a cantilever. These panels are supported on columns of the ordinary story height used in buildings.

The supporting columns for the slab were poured five days in advance of the slab, and the pouring of the slab itself required another five days. From each day's pouring 6 test samples were takan. Three of these samples are to be broken at the age of 30 days, and the others at intervals of 5 days thereafter. From the results, curves will be plotted to determine the time when the concrete attains the strength of 2,000 pounds per square inch in compression, and as soon after this date as possible the load tests of the slab will be started. Numerous steel plugs have been set in the concrete and tile for taking strain gage readings, as described above. Two large control beams and two standard bars 3′ × 3′ × 6″ were moulded from the concrete used in making the slab. These, together with representative specimens of the tile, will be used to obtain preliminary data.

THE BUREAU'S WORK IN THE FIELD OF RADIO COMMUNICATION.

The important work done by this government in the development of apparatus for radio telegraphy and telephony is only now becoming generally known. Information concerning this work was necessarily kept secret during the war, but recently several magazine articles have been published which have dealt with the government's investigations in a popular way. In connection with this development work, the Bureau took an active part and the numerous inquiries which have been received indicate that a few notes on the subject may not be out of place. The principal accomplishments of the war period were the development of the radio direction finder, and the electron tube. The first device is quite a new development and is so constructed that it receives radio waves and at the same time indicates the direction from which they come. During the war, it was very largely used in locating the position of enemy radio stations, both on land and sea. The electron tube may well be said to have revolutionized the art of radio communication and to have made practicable radio telephony. It has enabled American airplane pilots to talk with one another in flight.

Work in connection with the standardizing of these tubes was undertaken in connection with the Signal Corps and research work has been continued with a view to improving their action and increasing the knowledge concerning such devices.

Other investigations included the development of landing signals for airplanes, means for submarine radio communication, detecting devices, and the development of radio measurement. A number of publications, of both a technical and elementary character, were issued by the Bureau, among them being a manual of radio work.

Considerable difficulty has been experienced by airplanes in landing in the dark and in foggy weather. Particularly in war times airplanes are required to fly at high altitudes until they are behind their own lines and can safely descend. The Bureau, as mentioned in the previous paragraph, aided in the development of a system of airplane landing signals by means of which an airplane at high altitudes is able to tell when it is over its own landing field. The work was carried out for the Aerial Mail Service of the Postoffice Department, though it is equally applicable, as stated above, to the aerial service of the military departments.

Radio signals are sent from a transmitting station on the landing field and by means of a direction finder on the airplane the aviator is able to steer toward the source of these signals. On the landing field, there is provided a special kind of coil which emits signals, identical with the radio signals except for the fact that their effect does not extend much beyond the space immediately over the landing field. They are, therfore, heard by the aviator only when he crosses the field. On descending where these signals are loudest, he lands in the middle of the field. These landing signals are produced by the same generating apparatus on the ground as that used for the radio signals and both are received by the aviator with the same apparatus. The signals have been heard at a height as great as 6,400 feet.

PRINCIPLES OF RADIO TRANSMISSION AND RECEPTION WITH ANTENNA AND COIL AERIALS.

The ordinary type of antenna is satisfactory in the case of radio stations where plenty of space is available, such as those ordinarily constructed on land. In the case of airplanes, submarines, and other small vessels, it would be a great advantage to have some more compact form of transmitting and receiving mechanism. The relative advantages of the antenna or usual type of elevated aerial and the so-called coil aerial is an extremely important question and has recently been the subject of an investigation conducted at this Bureau. An article dealing with the work which has been accomplished along these lines was recently delivered in the form of a lecture at a joint meeting of the American Institute of Electrical Engineers and the Institute of Radio Engineers.

As a result of this work, it is now possible to determine by simple calculation the distance at which a given receiving aerial will receive signals from any transmitting aerial when the current in the aerial, its dimensions and the distance between the stations are known. It is obvious that the small coil aerial has many advantages, under the conditions as outlined in the first part of this paragraph, but it is usually not as powerful a transmitting and receiving device as the more common antenna type. The resistance of the coil aerial, however, may be so much lower than that of the antenna that it is equal to it in transmitting and receiving value. This work has brought about a better knowledge of the action of radio waves, a subject which up to this time has been but little understood.

INCREASING THE SPEED AND COLOR SENSITIVENESS OF PHOTOGRAPHIC PLATES.

It is well known that the ordinary photographic plate, when exposed in a camera, does not reproduce exactly what the eye sees. This is because the ordinary plate is affected by only blue, violet, and ultra-violet light to which the eye is relatively insensitive, and is scarcely at all affected by the green and yellow, for which the eye has its maximum sensitivity. These ordinary photographic plates are practically insensitive to red light and are, therefore, handled with safety in light from a ruby lamp. It has long been known, however, that photographic plates may be made sensitive to green, yellow and red light by the admixture of suitable dyes to the emulsions coated on the plates, and so-called orthochromatic and panchromatic plates have been on the market for years. The color sensitivity and speed of these commercial plates are not sufficiently great, however, to make them useful where

only short exposures can be used, as in photography from airplanes. Fortunately, it has been found that, at expense of keeping qualities, photographic plates of speed and color sensitiveness far superior to any commercial plates can be obtained by laboratory methods. A method in use for many years in the photography of spectra consists of bathing an ordinary blue and violet sensitive plate in a dilute solution of photo-sensitizing dyes. This method has been a continuous laboratory practice at the Bureau of Standards since 1913 for spectroscopic investigations and since 1917 a large number of experiments have been made in the use of such plates in aerial photography. The staining bath used in the preparation of these plates consists of a solution of dyestuff in a mixture of water, alcohol and ammonia. The effect of ammonia on the photo-sensitizing dyes was carefully investigated and it was found that the speed and color sensitiveness of commercial plates which have dyes incorporated in the emulsions, could be enormously increased by bathing such plates in a dilute solution of ammonia.

This method of hypersensitizing commercial panchromatic plates has also been used very successfully in aerial photography. For the comparison of different types of photographic plates, a four-lens camera in which various color sensitive plates could be placed behind lenses containing ray filters was used, and the advantages of plates highly sensitive to green, yellow, and red light have been strikingly shown. For example, in addition to the fact that a panchromatic plate reproduces more faithfully what the eye sees, it portrays objects, when exposed behind a ray filter or color screen, which, on account of haze, smoke, etc., would be hidden from an ordinary plate. Furthermore, it also gives different contrasts depending on the nature of the light transmitted to the plate through the filter. The phenomenon of haze penetration by the longer waves is known to most outdoor photographers. The blue sky and red sunset are proof that the blue or short light waves are scattered in the atmosphere and the red or longer waves are more readily transmitted. A red-sensitive photographic plate used in a camera with a red filter in the lens will, therefore, reveal objects which, owing to the obscuring presence of haze or smoke, fail to make any impression whatsoever on an ordinary blue-sensitive plate. To obtain these long-wave advantages of haze penetration and contrast, the photographic plates must have the greatest possible sensitiveness to yellow, orange, and red light if the lengths of exposure are necessarily short, either on account of rapidly moving objects, or, if the camera itself is in rapid motion, as is the case in aerial photography. A brief circular describing the practice of the Bureau of Standards in (1) bathing ordinary dry plates in solutions of photo-sensitizing dyes, and (2) treating commercially dyed plates with dilute ammonia has been prepared. Instrucions are given in the preparation of color sensitive photographic plates of maximum speed.

Progress of Science in America

Notes Furnished by the National Academy of Science

THE autumn meeting of the National Academy of Sciences was held at Yale University, New Haven, Connecticut, November 10 and 11. There were about 50 members of the Academy in attendance. An exceptionally pleasant feature of the meeting was the reception tendered by the President of Yale University and Mrs. Hadley at the Yale School of Fine Arts, where the famous Trumbull portraits of Washington and Hamilton and a very remarkable collection of old Italian paintings are preserved.

The luncheons at the New Haven Lawn Club, and an expedition to the laboratories of the Connecticut Agricultural Experiment Station were much enjoyed. At the Experiment Station papers were presented on the relation of particular vitamines to nutrition, and opportunity was given to see the colony of several hundred white rats on which the experiments are being conducted.

At the dinner of the Academy on November 11 the Daniel Giraud Elliot Medal was presented to Mr. C. William Beebe of the New York Zoological Park for his "Monograph of the Pheasants." The speech of presentation was made by Prof. Osborn of the American Museum, New York, who laid before the Academy the beautifully printed and illustrated monograph of Mr. Beebe. In an after dinner speech ex-President Taft expressed optimism with regard to the future of industrial relations of the United States and told amusing reminiscences of association with Roosevelt and others.

At the business meeting of the Academy the Henry Draper Gold Medal was awarded to Alfred Fowler, F.R.S., Professor of Astrophysics, Imperial College, South Kensington, London, for his researches in spectroscopy, relating especially to the spectra of terrestrial compounds and their occurrence in sunspots, and to stars of Secchi's Type III.

Announcement was made regarding the Mary Clark Thompson gift of $10,000 to establish a fund to be applied to a gold medal to be awarded annually by the Academy for the most important services to geology and paleontology.

The public sessions for the reading of papers were held in the Osborn Zoological Laboratory. Among papers of special interest was that of Prof. R. A. Millikan, of the University of Chicago, who showed photographs of the extreme ultra-violet spectrum extending as far as wave length 252 Angström units. The furthest extension hitherto was made by Lyman who reached the wave length 510 Angström units. In the spectrum of carbon Prof. Millikan found three lines which from various kinds of evidence he believes to be the same as the three lines of the L spectrum hitherto associated with the famous work of Mosely on the X-ray spectra of the elements. If Prof. Millikan's conclusion is confirmed the long gap between the X-ray spectra of the elements and their visible spectra will again be bridged. Certain lines of helium were found in the carbon spectrum which were so strong and persistent that the impression was produced in Prof. Millikan's mind that these were due to the breaking up of carbon in the intense spark, employed as the radiation source, with the formation of helium. This would be comparable to the well-known disintegration of radium with similar evolution of helium.

Dr. Simon Flexner gave a most interesting description of the past history, progress of the present epidemic, and symptoms of the disease, frequently spoken of as "sleeping sickness," which has appeared within about a year in the United States for the first time. The cause, method of propagation, and means of cure of this disease are as yet unknown, but Dr. Flexner expressed great hope that the efforts of investigators would enable these fundamental features to be discovered so that future epidemics might be checked.

Papers by Prof. E. B. Wilson and Dr. Leigh Page led to a discussion of the announcement recently made in England that the results of the British eclipse expeditions to Brazil and West Africa had confirmed the existence of a deflection of the light of the stars passing by the sun of the same magnitude as that predicted by Einstein's generalized theory of relativity. The discussion developed the point of view, es-

pecially among the experimental physicists present, that it is not necessary to suppose that the deviation of the light observed is really a proof of the soundness of the theory of relativity. Several other causes, as diffraction and refraction, might be operative to produce the small bending of the star rays seen. The impression prevailed that, so far as observations of any kind have yet gone, no one is compelled to adopt the difficult and obscure theory of relativity in place of other explanations of phenomena, unless he has the type of mind that prefers it.

Dr. Davenport presented results of medical examinations of drafted men. Statistical investigations had been completed as to the geographical distribution of defects of different kinds. Very curious distribution of certain kinds of sickness, malformation, and injuries was shown by maps. A discussion of the relative prevalence of these defects in drafted men from city and country districts showed in general that the healthfulness of the two were almost equal, although certain diseases appeared to be prevailingly country diseases and others prevailingly city diseases.

Dr. James B. Murphy showed that accompanying cancer grafts in immune animals there occurs a general increase in the circulating lymphocytes and hyperplasia of the lymphoid tissue. When the lymphoid tissue of immune animals was destroyed, the immunity was annulled. Two methods of increasing the lymphocytes have been found, namely, diffuse small doses of X-rays and dry heat. Mice with lymphocytosis induced by these methods have a high degree of resistance to transplanted cancer. Mice with spontaneous cancers treated by these agents show increased resistance to replants of their own tumors. The results afford grounds for hope of human application.

Dr. Hidayo Noguchi described his work in connection with the sanitary commission to study yellow fever at Guayaquil, Ecuador. Dr. Noguchi has been successful in producing yellow fever in guinea pigs and marmosets, and showed by lantern slides many characteristic curves of temperature and other symptoms of yellow fever in these animals. By these means and by special methods of staining he appears to have demonstrated the micro-organism of yellow fever for the first time as a spirochaeta which has hitherto escaped detection because of optical similarity to the medium invaded by it.

Dr. Henry Fairfield Osborn presented lantern slides of restorations of certain of the sauropod dinasaurs. These were given in continuation of his long investigations with his colleagues in these lines. He dwelt particularly on the necessity of studying the muscles and motions of the animals with relation to the most similar lving creatures. A true idea of their forms cannot be gained from skeleton remains alone. He intimated that a thorough understanding of their forms could only be had by such discussion of the animal in motion as might even involve the production of moving pictures in order to reach a satisfactory conclusion.

Dr. C. G. Abbot described a new method of determining the intensity of the solar radiation outside the atmosphere, by means of which the so-called "solar constant of radiation" may be determined by ten minutes of observation and two hours of computation better than it could be obtained before by three hours of observation and fifteen hours of computation. He also exhibited photographs of the total eclipse of May 29, 1919, taken at La Paz, Bolivia.

Dr. E. W. Brown exhibited the first copies to reach this country of his numerical tables of the moon's motion. These are the concrete result of many years of work by himself and his colleagues and may be expected to replace the tables of Hansen which have been used by nautical almanacs for the past sixty years.

ARTIFICIAL HONEY IN GERMANY.

ARTIFICIAL honey was consumed in Germany in large quantities during the war. Although the conversion of cane sugar into invert sugar is a simple chemical process, the products of different firms were lacking in uniformity, a considerable portion consisting of a thin fluid. For the production of a thick variety the water content and the inversion of the cane sugar are matters of great importance. The water content must not exceed 22 per cent and the inversion must be complete to within 5 per cent. The inversion proceeds best when at least 0.1 per cent of formic acid is present. The strongly acid taste of the product is removed by neutralising with sodium carbonate. The enactment of a law similar to that concerning margarine is recommended in order to prevent confusion between natural and artificial honey in the trade. On economic grounds, thick artificial honey is an indispensable product in Germany.—*From Schweiz. Chem.-Zeit.*, 1919.

CONDITIONS THAT GOVERN STALENESS IN BREAD.

IN a pamphlet bearing this title Capt. R. Whymper describes investigations carried out in the British Army bakeries in France during 1917-18. The results are given under four headings: I. Determination and location of losses occurring in the manufacture of bread; II. Conditions that govern staleness in bread. III. Changes occurring in bread with age. IV. The colloid nature of starch pastes, bread crumbs, etc. It was found that the cooling of bread takes place in three stages, namely, the steam period, during which most of the drying-out takes place in a given time; the condensation period, during which the rate of drying is only one-fifth that of the steam period; and the drying period in which the rate of drying is about one-fourth that of the steam period. Loss of moisture from the center of the loaf is inconsiderable until after 100 hours under ordinary conditions, an actual increase being often observed before this time. The zone of drying-out is very narrow in a loaf up to about 100 hours, being about 1 in. inwards from the crust; after 100 hours the moisture diffuses gradually from the center of the loaf, but at so slow a rate that there is always a pronounced difference between the moisture content of the crumb at the center of the loaf and that of the crumb beneath the crust. The loss of water during cooling and drying-out is not responsible for staleness. During the process of becoming stale the soluble extract of the crumb decreases, this decrease being followed after a time by an increase. The quantity of soluble starch in bread crumb diminishes rapidly betwen the sixth and twenty-fourth hours of the cooling period; a similar fall and rise of soluble extract is observed in starch pastes. Staleness may be attributed to deposition of solid starch in the crumb caused by change of temperature during the cooling period and accelerated by the presence of solid starch particles already existing in the crumb. Staleness is also due to polymerisation of starch, which tends to crumble the gelatinous nature of the bread crumb when fresh. Other changes occurring in the proteins of bread crumb may be responsible for staleness, but these have not yet ben investigated.—*From Jour. of the Soc. of Chem. Ind.*

SEA-GRASS FIBRE AS A PACKING MATERIAL

M. GLOESS, in the *Bulletin de l'Institut Oceanographique*, mentions the utility of sea-grasses as a packing material in place of wood-wool. The fibers of sea-grass are light, elastic, non-inflammable, odorless and non-rotting; advantages which are of considerable importance when perishable foodstuffs are being packed. It is stated that the elasticity of this material is three times as great as that of wood-wool, which means that notwithstanding the fact that the cost of production is somewhat higher, the use of sea-grass fibre would be twice as economical as the most economical packing hitherto employed. This material is slightly lighter than wood-wool.—Abstract from *La Nature*, Oct. 11, 1919, by the *Technical Review*.